
Debris/Ice/TPS Assessment And Photographic Analysis For Shuttle Mission STS-33R

December 1989

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Space Administration

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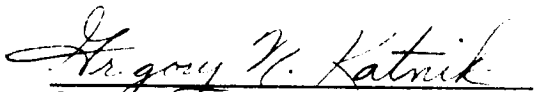
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OF
SHUTTLE MISSION STS-33R

November 22, 1989

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FORWARD

The Debris Team is continuing its effort to develop and implement measures to control damage from debris in the Shuttle operational environment and to make the control measures a part of routine processing and operations.



Launch of Shuttle Mission STS-33R on 11/22/89 at 7:23 p.m. EST

1.0 Summary

Debris and Photo Analysis Team activities for Mission STS-33R began with the pre-launch debris inspection of the launch pad and Shuttle vehicle on 21 November 1989. No major anomalies were observed on OV-103 Discovery, BIO-34, or ET-38. Minor facility discrepancies, which included loose MLP deck bolts, loose debris items under the raised deck, and facility debris inside the sound suppression water pipes, were corrected prior to cryo loading the vehicle.

No Orbiter or SRB anomalies were detected during the Ice Inspection. Condensate, but no ice or frost, was present on the acreage areas of the External Tank. Hard ice was present in the LO2 feedline bellows and support brackets. Light accumulations of ice on the LO2 ET/Orbiter umbilical were typical. The top and sides of the LH2 ET/Orbiter umbilical were covered by moderate, but typical, ice/frost. There was no ice or frost in the LH2 feedline bellows. A moderate amount of ice had formed in the LH2 recirculation line bellows. There were no unusual vapors emanating from the umbilicals or any evidence of leakage. Eight Ice/Frost console observation anomalies were documented and found acceptable for launch per the LCC and NSTS-08303. At launch, the ET ice condition was well within the data base for ice formation.

One new debris concern was identified during the inspection. An electrical connector cap on the east side of the LO2 TSM was loose and hanging from a retainer chain. The cap was re-attached and tightened. The third water trough (5th from the RH SRB nozzle) in the secondary sound suppression group had leaked and was nearly empty. Review/analysis/discussion by the launch team and the Mission Management Team determined this condition was acceptable for launch.

A post launch debris inspection of Pad 39B was performed two hours after launch. No significant flight hardware, except for three Q-felt plugs from the Orbiter base heat shield area, was found. Launch damage to the holddown posts was minimal. No signs indicative of stud hang-up were visible. No fragments from HDP debris containers were found. Although the GH2 vent line had latched properly, the vent arm retract lanyard had wrapped around the swivel housing assembly on the GUCP causing damage to the 7 inch QD sealing surface and breaking an electrical connector. Typical amounts of facility debris were found. The most significant item was a 3'x2' aluminum facility cable tray cover. Overall, the facility sustained minimal damage.

A total of 129 film and video items were analyzed as part of the post launch data review. No major vehicle damage or lost flight hardware was observed that would have affected the mission. However, a stud hang-up occurred on HDP #3. The momentary drag caused by this condition was detectable in the

Orbiter yaw accelerometer data. As the vehicle separated from the holddown post shoe, MLP films showed the stud extended 10.07 inches as the aft skirt foot cleared the HDP doghouse blast cover. The stud contacted the aft skirt stud hole wall and loosened a piece of shim material bonded to the aft skirt foot. The piece of shim, which included the inboard sidewall and a cutout for the stud, fell from the aft skirt foot and disappeared into the SRB exhaust hole. Other MLP cameras documented numerous particles of debris, some measuring 5 inches in length, moving upward from the SRB exhaust holes at high velocities. Some of the particles, which appeared to have a mass greater than foam, came close to impacting the vehicle.

The nearly-empty secondary sound suppression water trough was blown upward by the SRB ignition overpressure wave, reached the maximum extension of the tie down cords, and then flapped in the air flow. No visible adverse effects on the vehicle were caused by the absence of water in this trough.

Water run-off and condensate streamed from the rudder/speed brake split during early ascent. This is a normal occurrence and has been documented by KSC on previous vehicles.

Numerous pieces of debris fell from the vehicle during ascent. Most have been identified as ice/frost particles from the ET/Orbiter umbilicals, RCS paper covers, and Instafoam particles from the SRB aft skirts. Shortly after the roll maneuver, a large particle near the SSME plume aft of the vehicle can be traced to the LH SRB ETA ring area. The particles falling from the vehicle after Max Q are either pieces of SRB propellant or aft skirt Instafoam. At T+60 seconds, a piece of rope-like debris appeared to fall out of the RH SRB exhaust plume. The object was timed on 6 film items providing a consistent data base. The object appeared to drop out of the RH SRB plume or become visible around the aft skirt area (as seen from the ground). Although the object appeared as a dot in distant range northern views, the object appeared to be an elongated streak in close-up films, possibly the result of slow film speeds or camera shake. Since the southern cameras, which had a clear view of the Orbiter aft end, recorded no objects during this time, it seems likely the object originated from the SRB aft skirt area. The object was a piece of burning propellant and/or inhibitor. 'Clinkers' in the SRB plumes prior to and just after separation from the External Tank are chunks of SRB propellant slag.

The Solid Rocket Boosters were inspected at Hanger AF after retrieval. Both forward skirts and frustums exhibited a total of 21 debonds, but no areas of missing TPS. The BSM aero heat shield covers had locked, but the attach rings had been bent by parachute riser entanglement. The phenolic plates on two of the RSS antennae were delaminated and missing some material.

The factory joint EPDM moisture seals on the RH forward and LH aft segments exhibited debonds. Two cracks appeared in the LH aft field joint where the trunnion had been potted in with K5NA. Instafoam was missing from the aft side of the LH ETA ring behind the IEA. Broken foam and exposed cork substrate were sooted. The area of missing foam measured 3 feet long by the width of the ETA ring and was probably the piece observed falling from the vehicle in the film review.

Holddown post #3 aft skirt foot hole showed evidence of stud hang-up. Thread marks from the Inconel stud were impressed around the forward inner aluminum surface of the hole. The stud abraded a 1/2-inch deep chamfer inclined 45 degrees on the inboard aft edge of the hole by the broaching. Stud hang-ups have occurred on six previous flights (STS-2, 4, 51-I, 51-J, 61-A, and 34). Holddown post shoes had lifted on STS-2, 29, and 34, but were not lifted on this launch.

A post landing inspection of OV-103 was performed on Runway 22. The Orbiter TPS sustained a total of 118 hits, of which 21 had a major dimension of one inch or greater. The Orbiter lower surface had a total of 107 hits, of which 21 had a major dimension of one inch or greater. Based on these numbers and comparison to statistical data from previous missions of similar configuration, the number of hits on the lower surface is average. Also, based on the severity of damage as indicated by surface area and depth, this flight is better than average.

The single largest tile damage site occurred on the right side of the rudder/speed brake and involved two trailing edge tiles. These tiles were not damaged by debris impacts, but probably were the result of the combined launch environment (acoustics, heating, etc). The SSME engine mounted heat shield closeout blankets were damaged and frayed. White streaks/deposits were present on both wing leading edge RCC panels. Window #3 was heavily hazed, window #4 was lightly hazed, and windows #5 was streaked. The separation ordnance devices functioned properly and the debris plungers seated on EO-2 and EO-3. A detailed inspection of EO-1 revealed the ordnance device had rotated forward sufficiently to contact and break the LH bulkhead pyro connector backshell. There is also evidence of this contact on the ordnance device LH spring housing. No flight hardware was found during the runway walkdown after landing.

A total of 26 material samples were taken from the Orbiter after landing for laboratory analysis. The samples revealed components of SRB BSM residue, paint, thermal protection system materials, cleaning agent residue, and landing site products. This mission exhibited no evidence of orbital debris impacts, unusual debris concerns, or unexplained debris sample analyses.

A total of 23 Post Launch Anomalies were documented for this mission.

2.0 KSC ICE/FROST/DEBRIS TEAM ACTIVITIES

Team Composition: NASA KSC, NASA MSFC, NASA JSC,
LSOC SPC, RI - DOWNEY, MMMSS - MAF,
USB1 - BPC, MTI - UTAH

Team Activities:

1) Prelaunch Pad Debris Inspection

Objective: Identify and evaluate potential debris material/sources. Baseline debris and debris sources existing from previous launches.

Areas: MLP deck, ORB and SRB flame exhaust holes, FSS, Shuttle vehicle external surfaces

Time: L - 1 day

Requirements: OMRSD S00U00.030 - An engineering debris inspection team shall inspect the shuttle and launch pad to identify/resolve potential debris sources. The prelaunch vehicle/pad configuration shall be documented/photographed.

Documents: OMI S6444

Report: Generate PR's and recommend corrective actions to pad managers.

2) Launch Countdown Firing Room 2

Objective: Evaluate ice/frost accumulation on the shuttle vehicle and/or any observed debris utilizing OTV cameras.

Areas: MLP deck, FSS, Shuttle vehicle external surfaces

Time: T - 6 hours to Launch + 1 hour or propellant drainback

Requirements: OMRSD S00FB0.005 - Monitor and video tape record ET TPS surfaces during loading through prepressurization.

Documents: OMI S0007, OMI S6444

Report: OIS call to NTD, Launch Director, and Shuttle managers. Generate IPR's.

3) Ice/Frost TPS and Debris Inspection

Objective: Evaluate any ice formation as potential debris material. Identify and evaluate any ORB, ET, or SRB TPS anomaly which may be a debris source or safety of flight concern. Identify and evaluate any other possible facility or vehicle anomaly.

Areas: MLP deck, FSS, Shuttle vehicle external surfaces

Time: T - 3 hours (during 2 hour BIH)

Requirements: OMRSD S00U00.020 - An engineering debris inspection team shall inspect the shuttle for ice/frost, TPS, and debris anomalies after cryo propellant loading. Evaluate, document, and photograph all anomalies. During shuttle walkdown inspect orbiter aft engine compartment (externally) for water condensation and/or ice formation in or between aft compartment tiles. An IR scan is required during the shuttle inspection to verify ET surface temperatures. During shuttle walkdown, inspect ET TPS areas which cannot be observed by the OTV system.

Documents: OMI S0007, OMI S6444

Report: Briefing to NTD, Launch Director, Shuttle management; generate IPR's.

4) Post Launch Pad Debris Inspection

Objectives: Locate and identify debris that could have damaged the Shuttle vehicle during launch.

Areas: MLP deck, flame exhaust holes and trenches, FSS, pad surfaces and slopes, extension of trenches to perimeter fence, walkdown of the beach from Playlinda to Complex 40, aerial overview of inaccessible areas.

Time: Launch + 3 hours (after pad safing, before washdown)

Requirements: OMRSD S00U00.010 - An engineering debris inspection team shall perform a post launch pad/area inspection to identify any lost flight or ground systems hardware

and resultant debris sources. The post launch pad/area configuration shall be documented/photographed.

Documents: OMI S0007, OMI S6444
Report: Initial report to LTD and verbal briefing to Level II at L+8 hours; generate PR's.

5) Launch Data Review

Objective: Detailed review of high speed films video tapes, and photographs from pad cameras, range trackers, aircraft and vehicle onboard cameras to determine possible launch damage to the flight vehicle. Identify debris and debris sources.

Time: Launch + 1 day to Launch + 6 days

Requirements: OMRSD S00U00.011 - An engineering film review and analysis shall be performed on all engineering launch film as soon as possible to identify any debris damage to the space shuttle vehicle. Identify flight vehicle or ground system damage that could affect Orbiter flight operations or future SSV launches.

Documents: OMI S6444
Report: Daily reports to Level II Mission Management Team starting on L+1 day through landing; generate PR's.

6) SRB Post Flight/Retrieval Inspection

Objective: Evaluate potential SRB debris sources. Data will be correlated with observed Orbiter post landing TPS damage.

Areas: SRB external surfaces (Hangar AF, CCAFS)

Time: Launch + 24 hours (after on-dock, before hydrolasing)

Requirements: OMRSD S00U00.013 - An engineering debris damage inspection team shall perform a post retrieval inspection of the SRB's to identify any damage caused by launch debris. Any anomalies must be documented/photographed and coordinated with the results of the post launch shuttle/pad area debris inspection.

Documents: OMI B8001
Report: Daily reports to Level II Mission Management Team. Preliminary report to SRB Disassembly Evaluation Team. Generate PR's.

7) Orbiter Post Landing Debris Damage Assessment

Objective: Identify and evaluate areas of damage to Orbiter TPS due to debris and correlate, if possible, source and time of occurrence. Additionally, runways are inspected for debris and sources of debris.

Areas: Orbiter TPS surfaces, runways

Time: After vehicle safing on runway, before towing

Requirements: OMRSD S00U00.040 - An engineering debris inspection team shall perform a prelanding runway inspection to identify, document, and collect debris that could result in Orbiter damage. Runway debris and any facility anomalies which cannot be removed/corrected by the Team shall be documented and photographed; the proper management authority shall be notified and corrective actions taken.

Requirements: OMRSD S00U00.050 - An engineering debris inspection team shall perform a post landing runway inspection to identify and resolve potential debris sources that may have caused vehicle damage but was not present or was not identified during pre-launch runway inspection. Obtain photographic documentation of any debris, debris sources, or flight hardware that may have been lost on landing.

Requirements: OMRSD S00U00.060 - An engineering debris inspection team shall map, document, and photograph debris-related Orbiter TPS damage and debris sources.

Requirements: OMRSD S00U00.012 - An engineering debris damage inspection team shall perform a post landing inspection of the Orbiter vehicle to identify any damage caused by launch debris. Any anomalies must be documented/

photographed and coordinated with the results of the post launch shuttle/pad area debris inspection.

Requirements: OMRSD V09AJ0.095 - An engineering debris inspection team shall perform temperature measurements of RCC Nose Cap and RCC RH Wing Leading Edge Panels 9 and 17.

Documents: OMI S0026, OMI S0027, OMI S0028

Report: Briefing to NASA Convoy Commander and generate PR's. Preliminary report to Level II on the day of landing followed by a preliminary update the next day.

8) Level II report

Objective: Compile and correlate data from all inspections and analyses. Results of the debris assessment, along with recommendations for corrective actions, are presented directly to Level II via SIR and PRCB. Paper copy of complete report follows in 3 to 4 weeks. (Ref NASA Technical Memorandum series).

3.0 PRE-TEST BRIEFING

The Ice/Frost/Debris Team briefing for launch activities was conducted on 21 November 1989 at 1200 hours with the following key personnel present:

C. Stevenson	NASA - KSC	Chief, ET Mechanical Systems Lead, Ice/Debris Assess Team
G. Katnik	NASA - KSC	ET Mech/TPS, Ice/Debris Assessment, STI
S. Higginbotham	NASA - KSC	STI, Debris Assessment
B. Speece	NASA - KSC	ET Processing, Ice Assess
B. Bowen	NASA - KSC	ET Processing, "SURFICE"
J. Rivera	NASA - KSC	ET Processing, Debris Assess
A. Oliu	NASA - KSC	"SURFICE", Debris Assess
M. Bassignani	NASA - KSC	ET Processing, Ice Assess
B. Davis	NASA - KSC	STI, Debris Assessment
K. Tenbusch	NASA - KSC	"SURFICE", Debris Assess
J. Hoffman	LSOC - SPC	ET Processing, Ice Assess
M. Young	LSOC - SPC	ET Processing, Ice Assess
J. Cawby	LSOC - SPC	ET Processing, Ice Assess
R. Seale	LSOC - SPC	ET Processing, Ice Assess
J. Blue	LSOC - SPC	ET Processing, Ice Assess
F. Huneidi	NASA - MSFC	TPS & Ice Assessment
Z. Byrns	NASA - JSC	Level II Integration
C. Gray	MMC - MAF	ET TPS & Materials Design
S. Copsey	MMC - MAF	ET TPS Testing/Certif
K. Ely	MMC - KSC	ET Processing, LSS
J. McClymonds	RI - Downey	Debris Assess, LVL II Integ
K. Mayer	RI - LSS	Orbiter Integration
H. Novak	USBI - PSE	SRB Processing
J. Maw	MTI - Utah	SRM Plant Representative

These personnel participated in various team activities, assisted in the collection and evaluation of data, and contributed to reports contained in this document.

3.1 PRE-LAUNCH SSV/PAD DEBRIS INSPECTION

The pre-launch debris inspection of the pad and Shuttle vehicle was conducted on 21 November 1989 from 1330 - 1600 hours. The detailed walkdown of Launch Pad 39B and MLP-2 also included the primary flight elements OV-103 Discovery (9th flight), ET-38 (LWT-31), and BI0-34. Documentary photographs were taken of facility anomalies, potential sources of vehicle damaging debris, and new vehicle configurations.

There were no major vehicle anomalies. However, 3 pieces of tape adhering to the AFRSI blankets on the left side of the vertical stabilizer were reported to the Orbiter TPS group and removed before flight.

Due to the continued concern over potential hydrogen leakage from the ET/ORB LH2 umbilical interface area during the cryoload/launch of STS-28R, a temporary hydrogen detector was installed at the ET/ORB LH2 umbilical until a permanent sensor can be designed and installed. The temporary detector consists of two tygon tubes that run from the LH2 umbilical area to the hazardous gas detection equipment located on the FSS. The tubes were attached to the vehicle by three velcro strap assemblies. A length of parachute cord attached to these assemblies enable the entire apparatus to be quickly removed from the vehicle without causing TPS damage. The hydrogen sensor is intended to remain in place during cryo loading and be removed by the Ice Inspection Team during the T-3 hour hold.

A recurring problem is loose MLP deck bolts. This inspection revealed loose deck bolts in the access standoffs east of the RH SRB, east of the LO2 TSM, adjacent to holddown posts #5 and #6, and adjacent to the HDP-2 access ladder. Handrail grounding bolts were loose around the SRB exhaust holes.

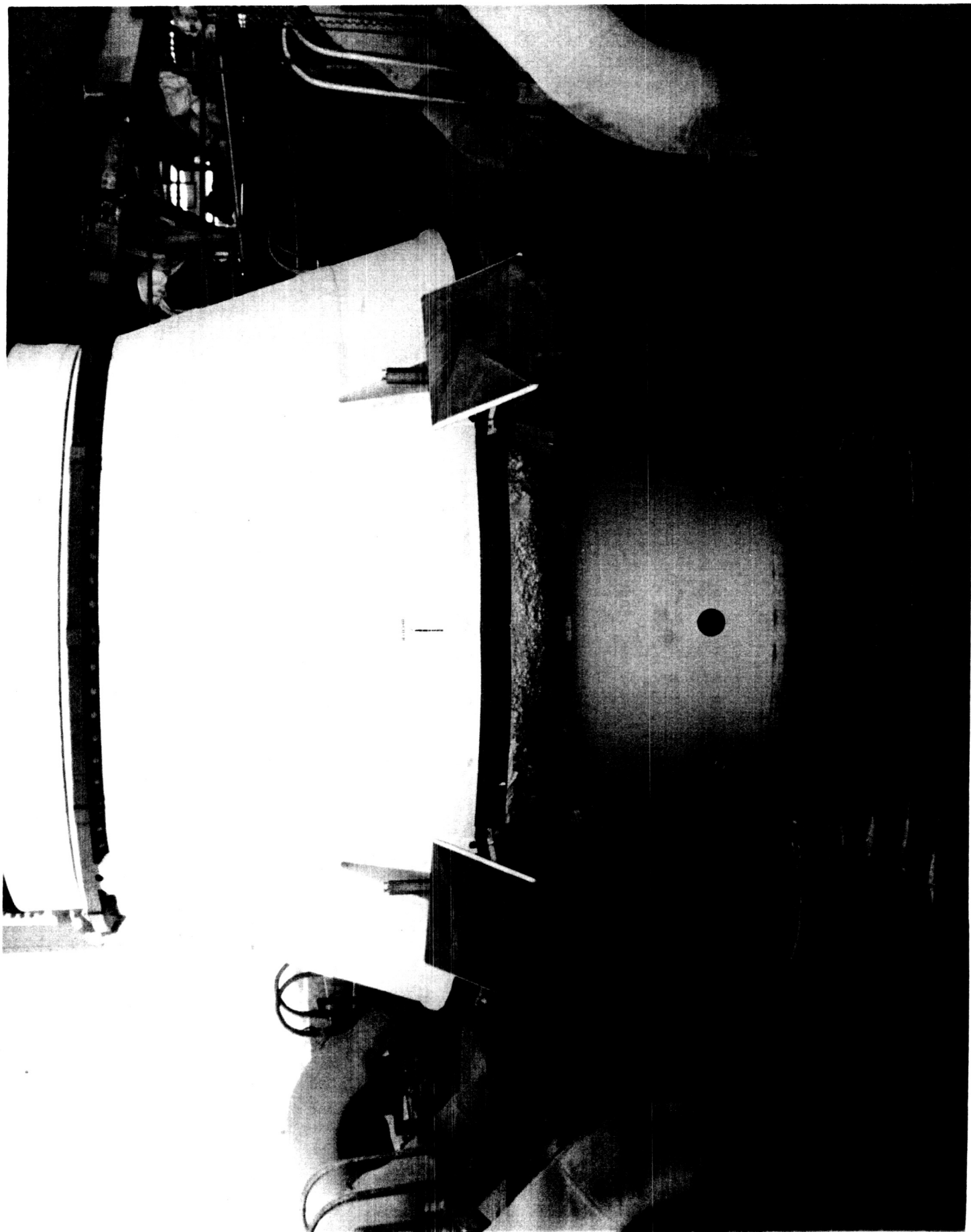
Several sections of the sound suppression water pipe were removed for access to the SRB holddown post haunches. A clip, blade, and other debris was visible in the pipe on the west side of the LH SRB exhaust hole.

Covers on the Portable Purge Unit (PPU) electrical receptacle in the northwest corner of the MLP were loose. Unattached metal plates adjacent to the HDP #2 access ladder and under the water pipe east of the RH SRB exhaust hole lay on the MLP deck. A curved pipe and electrical connector plug were loose east of the RH SRB exhaust hole.

Other miscellaneous items include eroded washers at the SRB sound suppression water trough tie downs, protective padding on a Firex water nozzle pointed at the Orbiter tail, and Instafoam particles/TPS trimmings on the MLP deck and in the holddown post haunch areas.

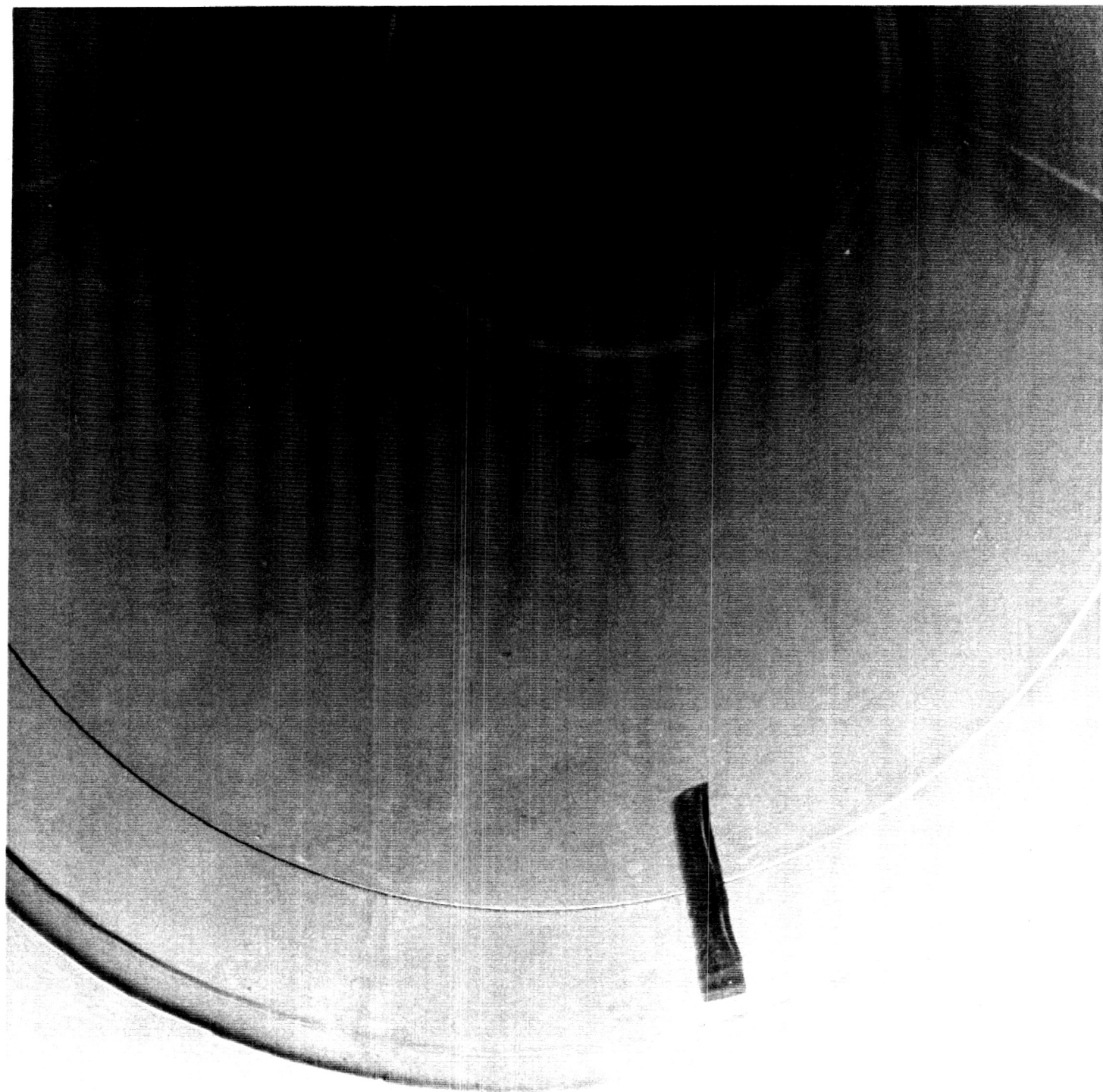
Excessive RTV had been applied to the instrumentation bands at the base of the SRB holddown posts, but was removed prior to launch.

Cleanup of the MLP deck and pad surface was behind schedule due to the replacement of SRB IEA's and retest (hot fire) of the HPU's. The facility discrepancies were listed in Appendix K of the countdown OMI S0007 for resolution prior to vehicle tanking.

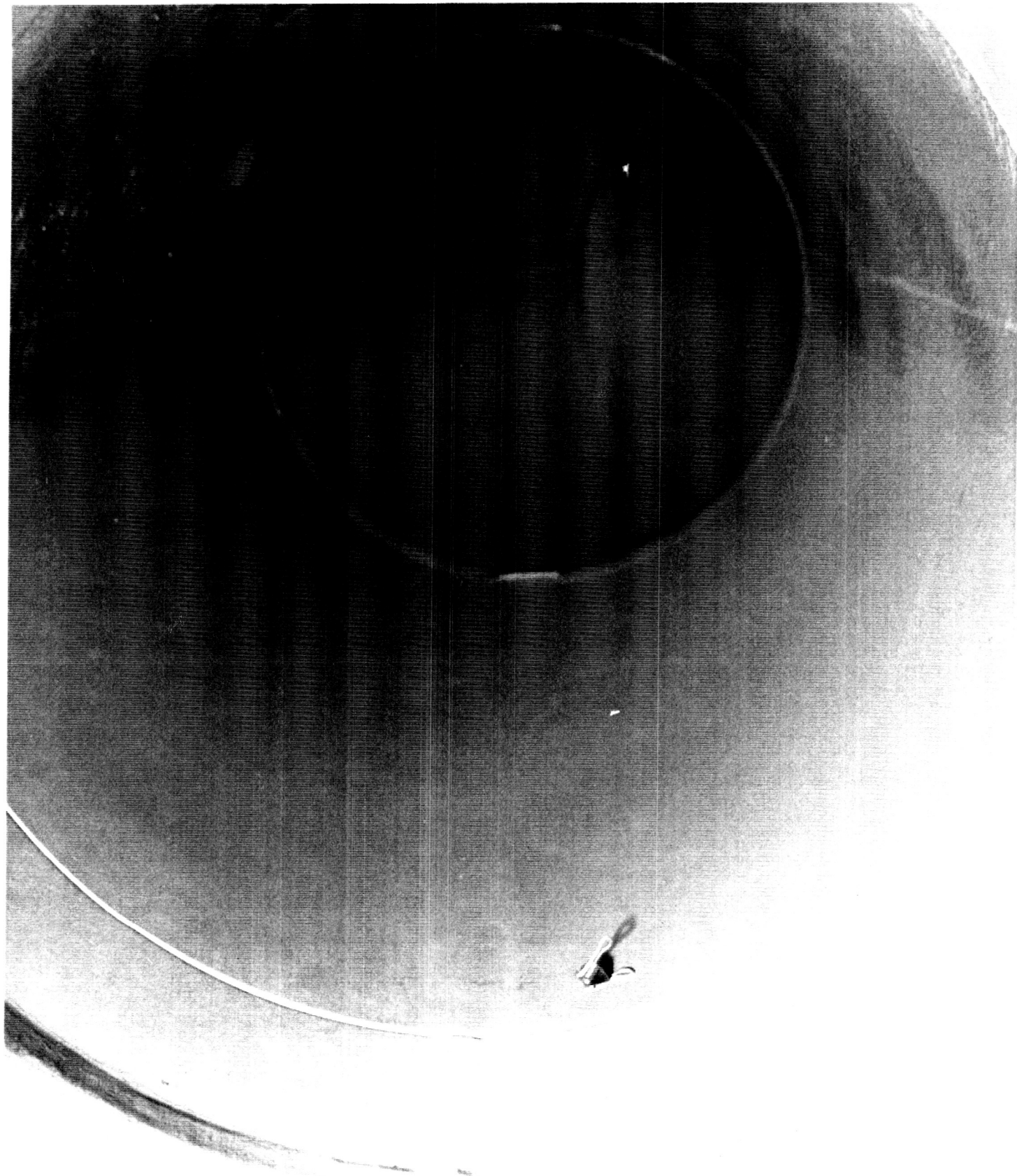


RH SRB secondary sound suppression water troughs were full of
water at T-24 hours in the countdown

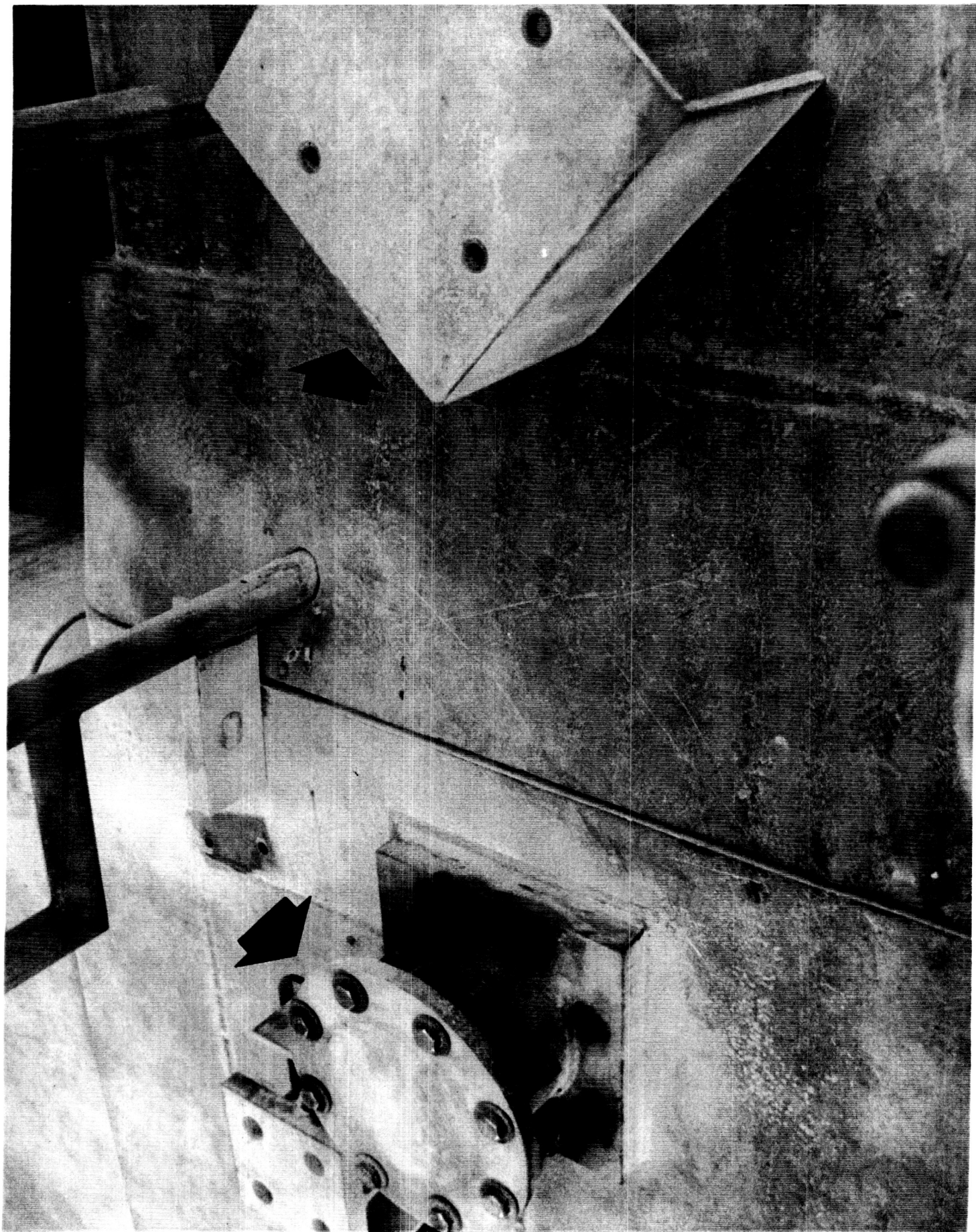
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Blade and other facility debris in the sound suppression water
pipe on the west side of the LH SRB exhaust hole



Clip and other facility debris in the sound suppression water
pipe on the west side of the LH SRB exhaust hole



Bolts from portable hoist were left in the pedestal near the
RH SRB exhaust hole. Note loose deck cover on right side.



RTV correctly applied to instrumentation bands on the HDP base.
Note Instafoam and K5NA trimmings in HDP haunch area.

4.0 LAUNCH

STS-33R was launched on the first attempt at 1923 EST (GMT 00:23:30.044) on 22 November 1989.

4.1 ICE/FROST INSPECTION

The Ice/Frost Inspection of the cryoloaded vehicle was performed on 22 November 1989 from 1310 to 1500 hours during the two hour built-in-hold at T-3 hours in the countdown. There were no violations of NSTS-08303 or the Launch Commit Criteria. Ambient weather conditions at the time of the inspection were:

Temperature:	71.4 F
Relative Humidity:	79.3 %
Wind Speed:	8 Knots
Wind Direction:	200 Degrees

The portable STI infrared scanner was utilized to obtain surface temperature measurements for an overall thermal assessment of the vehicle, as shown in Figure 1 and 2.

4.2 ORBITER OBSERVATIONS

No Orbiter tile anomalies were observed. The average Orbiter surface temperature was recorded as 68 degrees F. The average surface temperatures of the SSME engine mounted heat shields were measured at 68 degrees F for SSME #1, 67 degrees F for SSME #2, and 67 degrees F for SSME #3. A small amount of ice and frost was visible on the nozzle to heat shield interface of SSME #1 6 o'clock position and SSME #2 3 o'clock position. Condensate was present on SSME #1 and #2 engine mounted heat shields. There was no ice/frost or condensate on the SSME #3 heat shield.

4.3 SOLID ROCKET BOOSTER OBSERVATIONS

No SRB anomalies or loose ablator/cork were observed. The STI portable infrared scanner recorded RH and LH SRB case surface temperatures at 65 degrees F. Temperatures in the area of the SRB field joint heater closeouts ranged from 74 to 77 degrees F. The predicted Propellant Mean Bulk Temperature (PMBT) supplied by MTI was 73 degrees F.

FIGURE 1. INFRA RED SCANNER SSV SUMMARY DATA

TIME: 1300-1500
 DATE: 11/22/89
 VEH. STS- 33R

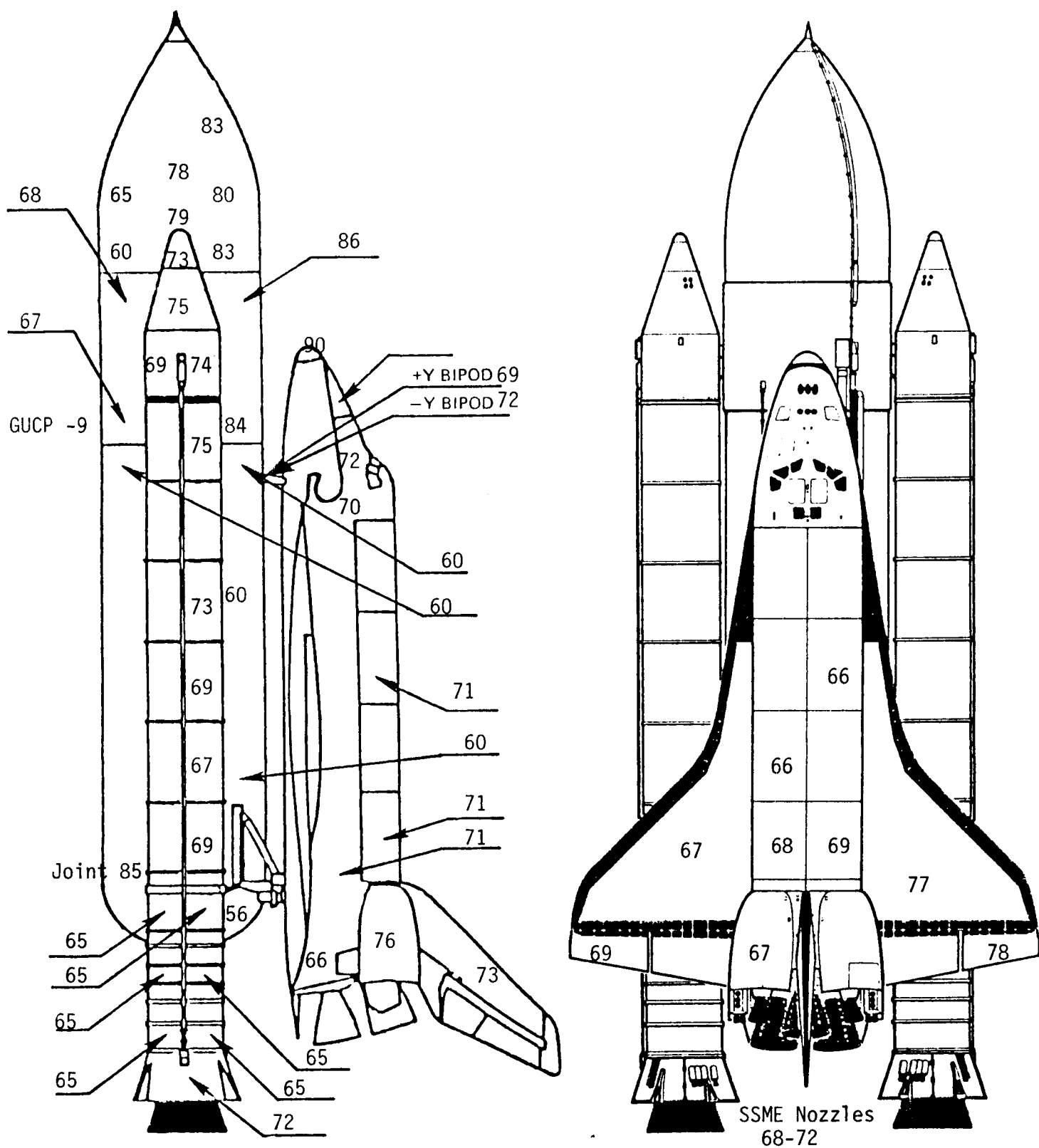
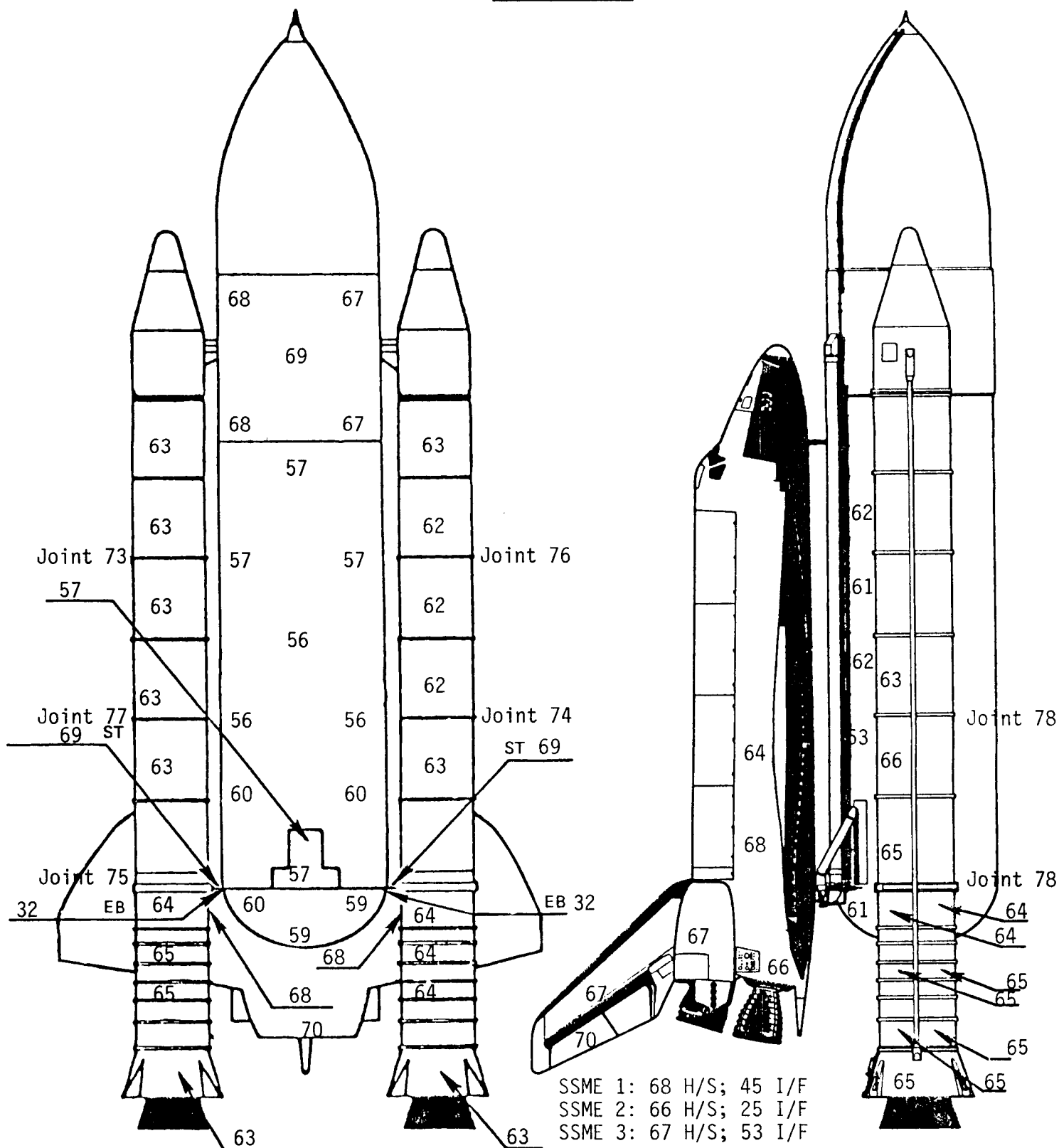


FIGURE 2. INFRA RED SCANNER SSV SUMMARY DATA

TIME: 1300 - 1500
 DATE: 11/22/89
 VEH. STS-33R



4.4 EXTERNAL TANK OBSERVATIONS

The ice/frost prediction computer program was run from 1000 to 1923 hours and the results tabulated in Figures 3, 4, and 5. The program predicted condensate with no ice accumulation on all TPS acreage surfaces.

The IR scanner measured an average surface temperature of 61-65 degrees F on the LO2 tank, 68 degrees F on the Intertank, and 56-60 degrees F on the upper and lower LH2 tank.

A minimal amount of condensate was present on the LH2 tank. There was no acreage ice or frost. No TPS anomalies were observed. Light frost spots were present on the LH2 tank aft dome apex and manhole cover. These spots were acceptable per NSTS-08303.

Ice/Frost covered the lower EB fittings outboard to the strut pin hole with condensate on the rest of the fitting. The struts were dry and not covered by ice.

The LO2 ET/ORB umbilical exhibited very light accumulations of ice on the inboard and aft sides. Frost fingers had formed on the purge vents and normal venting was occurring.

There was no ice or frost in the LH2 feedline bellows. A moderate amount of ice had formed in the LH2 recirculation line bellows, but this was acceptable per NSTS-08303. The top and sides of the LH2 ET/ORB umbilical were covered by moderate, but typical, ice/frost. This coverage is acceptable per NSTS-08303. Frost fingers had formed on the purge vents and normal venting was occurring. There were no unusual vapors emanating from the umbilicals or any evidence of leakage.

Hard ice was present in the LO2 feedline bellows and all of the support brackets. This condition is acceptable per NSTS-08303.

A minimal amount of run-on condensate from the LO2 tank was present on the intertank. Ice had formed in 9 areas in the stringer valleys at the LO2 tank-to-intertank flange (-Y-Z). There were 9 more ice areas in the stringer valleys at the LH2 tank-to-intertank flange (-Y-Z). These ice areas were outside the debris zone. No TPS anomalies were observed. Minor frost had formed around the GUCP, but there was no sign of leakage.

Condensate on the LO2 tank ogive and barrel section was very light. There was no ice or frost on the acreage areas. No TPS anomalies were observed.

The tumble valve cover was properly installed and intact with no sign of degradation.

STS - 33R		TEST:				S0007 Launch				DATE:		T-0 TIME: 19:23:30		DATE: 11/22/89		DATE: 11/22/89									
ORBITER	ET	SRB	MLP	PAD	LO2	LO2	LO2	LO2	LO2	LO2	LO2	LO2	LO2	LO2	LO2	LO2									
OV- 103	38	B1034	2	B	CHILLDOWN TIME: 0924	FAST FILL TIME: 1030	CHILLDOWN TIME: 0805	FAST FILL TIME: 1022	CHILLDOWN TIME: 0953	FAST FILL TIME: 1228	CHILLDOWN TIME: 1030	FAST FILL TIME: 1236	CHILLDOWN TIME: 0805	FAST FILL TIME: 1022	CHILLDOWN TIME: 0953	FAST FILL TIME: 1228									
CONDITIONS																									
LOCAL TIME		TEMP. OF	REL HUM. %	DEW PT OF	WIND VEL KNTS	WIND DIR DEG	REGION	LOCAL VEL KNTS	SOFI TEMP OF	COND RATE IN/HR	ICE RATE IN/HR	REGION	LOCAL VEL KNTS	SOFI TEMP OF	COND RATE IN/HR	ICE RATE IN/HR									
LO2 TANK STA 370 TO 540																									
1000	64	81	58.15	3	181	II	1.77	46.50	.0017	.0437	II	1.77	37.61	.0026	.0194	II	1.26	36.03	.0028	.0139	II	1.14	36.03	.0028	.0139
1030	65	81	59.13	3	207	II	1.77	47.68	.0018	.0481	II	1.77	38.82	.0026	.0237	II	0.96	37.25	.0028	.0183	II	4.08	46.71	.0037	.0677
1100	66	81	60.12	4	237	II	2.36	50.88	.0019	.0649	II	2.36	43.23	.0030	.0373	II	1.28	38.47	.0029	.0227	II	5.44	50.62	.0039	.1058
1130	69	80	62.74	4	237	II	2.36	54.11	.0020	.0776	II	2.36	46.68	.0032	.0496	II	1.28	41.96	.0031	.0359	II	5.44	53.80	.0041	.1268
1200	74	79	67.33	6	224	II	3.54	61.87	.0022	.1404	II	3.54	56.50	.0038	.1106	II	1.92	48.68	.0035	.0602	II	8.16	62.01	.0043	.2493
1215	75	79	68.32	7	169	II	4.13	63.72	.0022	.1669	II	4.13	59.00	.0040	.1365	II	2.94	54.76	.0040	.0911	II	2.66	53.68	.0039	.0816
1230	74	79	67.33	9	160	II	5.31	63.75	.0021	.1977	II	5.31	59.81	.0040	.1668	II	3.78	56.07	.0042	.1127	II	3.42	55.09	.0041	.1012
1245	73	79	66.34	9	162	II	5.31	62.68	.0021	.1892	II	5.31	58.69	.0039	.1586	II	3.78	54.89	.0041	.1063	II	3.42	53.90	.0040	.0951
1300	74	79	67.33	8	169	II	4.72	63.24	.0021	.1788	II	4.72	58.92	.0039	.1482	II	3.36	54.00	.0041	.0922	II	3.04	53.90	.0040	.0888
1315	74	79	67.33	10	169	II	5.90	64.17	.0020	.2165	II	5.90	60.55	.0040	.1852	II	4.20	57.04	.0042	.1262	II	3.80	57.12	.0042	.1134
1330	73.6	79.267.01	13	177	II	7.67	64.75	.0018	.2681	II	7.67	61.82	.0039	.2361	II	5.46	58.85	.0043	.1629	II	4.94	58.04	.0043	.1468	
1345	73.6	79.267.01	12	176	II	7.08	64.48	.0019	.2499	II	7.08	61.34	.0039	.2181	II	5.04	58.21	.0043	.1499	II	4.56	57.36	.0043	.1349	
1400	74.6	79.267.99	10	199	II	5.90	64.85	.0021	.2225	II	5.90	61.27	.0040	.1911	II	4.20	57.79	.0043	.1307	II	3.80	56.87	.0042	.1176	
1415	76.0	79.269.38	7	189	II	4.13	64.85	.0022	.1747	II	4.13	60.20	.0040	.1440	II	2.94	56.00	.0041	.0971	II	2.66	54.96	.0040	.0872	
1430	75	79	68.32	10	175	II	5.90	65.23	.0020	.2258	II	5.90	61.66	.0040	.1943	II	4.20	58.20	.0043	.1332	II	3.80	57.29	.0042	.1200

EGUV-340

FIGURE 3. Ice/Frost Computer Predictions

[illegible]

FIGURE 5. Ice/Frost Computer Predictions

The ET/ORB hydrogen detection sensor tygon tubing was removed with no damage to the vehicle.

The summary of ice/frost team observation anomalies consists of 8 OTV recorded items:

Anomaly 001 documented a white, "S"-shaped object inside the ET/ORB L02 umbilical baggie. An inspection team viewed the area and determined the object was really moisture/condensate inside the baggie creating a reflection.

Anomaly 002 recorded ice formation on the outboard edges of the ET/ORB LH2 and L02 umbilical baggies. The ice formation in these areas are acceptable per NSTS-08303.

Ice/frost appeared to be developing at the interface of the GUCP and intertank acreage (Anomaly 003). Ice/frost development in this area is acceptable per NSTS-08303.

Anomaly 004 documented ice/frost accumulation in the L02 feedline bellows and in the support brackets (XT 1623 and XT 1851). On-pad inspection determined ice/frost had accumulated in all of the L02 feedline bellows and support brackets. Ice/frost accumulation in these areas are acceptable per NSTS-08303.

Anomaly 005 recorded ice/frost formation on the ET aft dome -Z manhole cover leak check port closeout. The ice had formed early in the tanking operation, but had melted before the Ice Inspection Team arrived at the pad.

Frost accumulated in the +Y thrust strut to longeron interface area (Anomaly 006). However, no ice or frost was visible in the area during the Ice Team inspection.

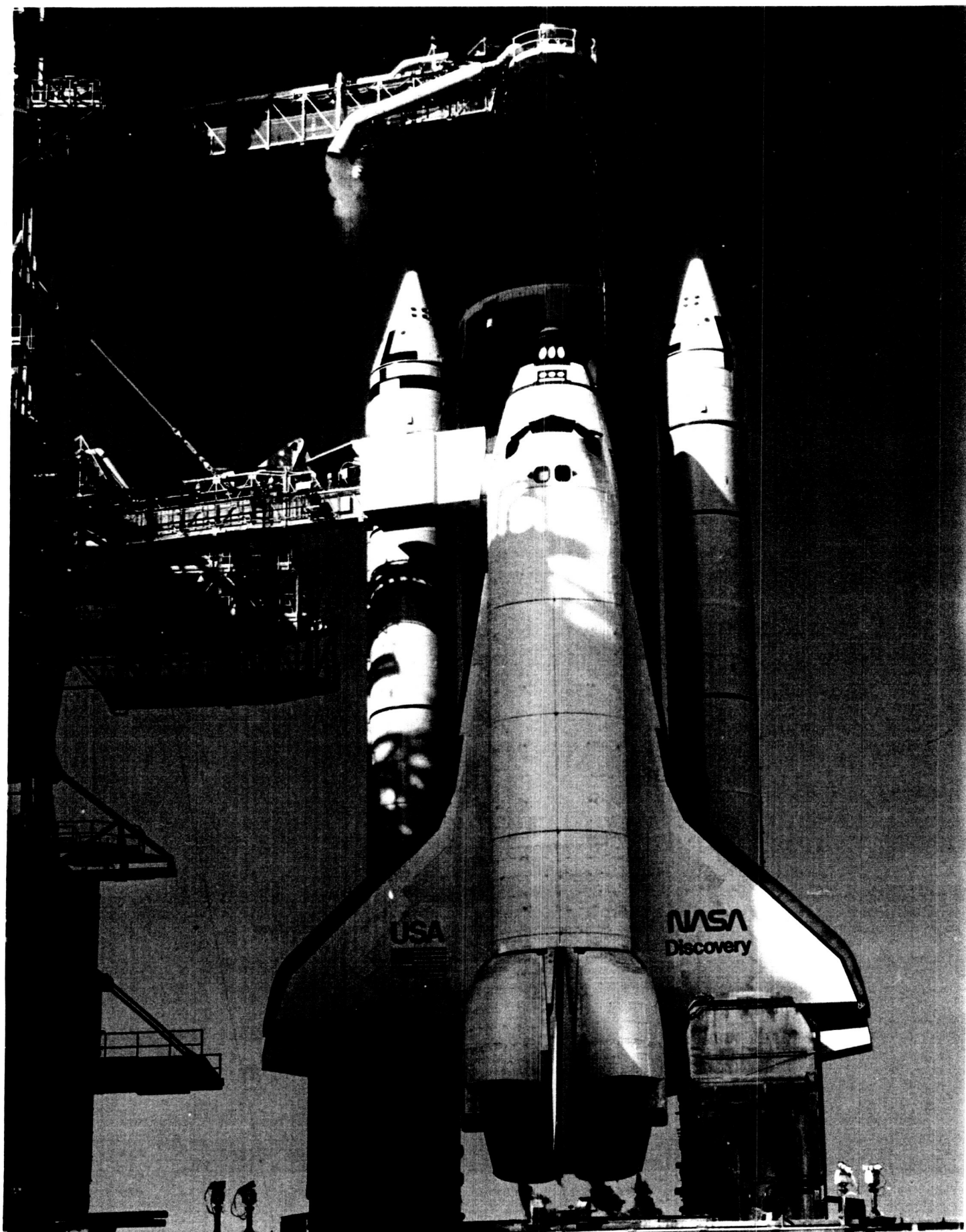
Anomaly 007 documented the accumulation of frost at the end of the south GOX vent duct. Frost accumulation of this amount and at this location is acceptable per NSTS-08303.

Anomaly 008 recorded frost accumulation in the intertank stringer valleys at the L02 tank-to-intertank flange and the LH2 tank-to-intertank flange in the -Y-Z quadrant (total of 9 at each location). Frost in this area is acceptable per NSTS-08303.

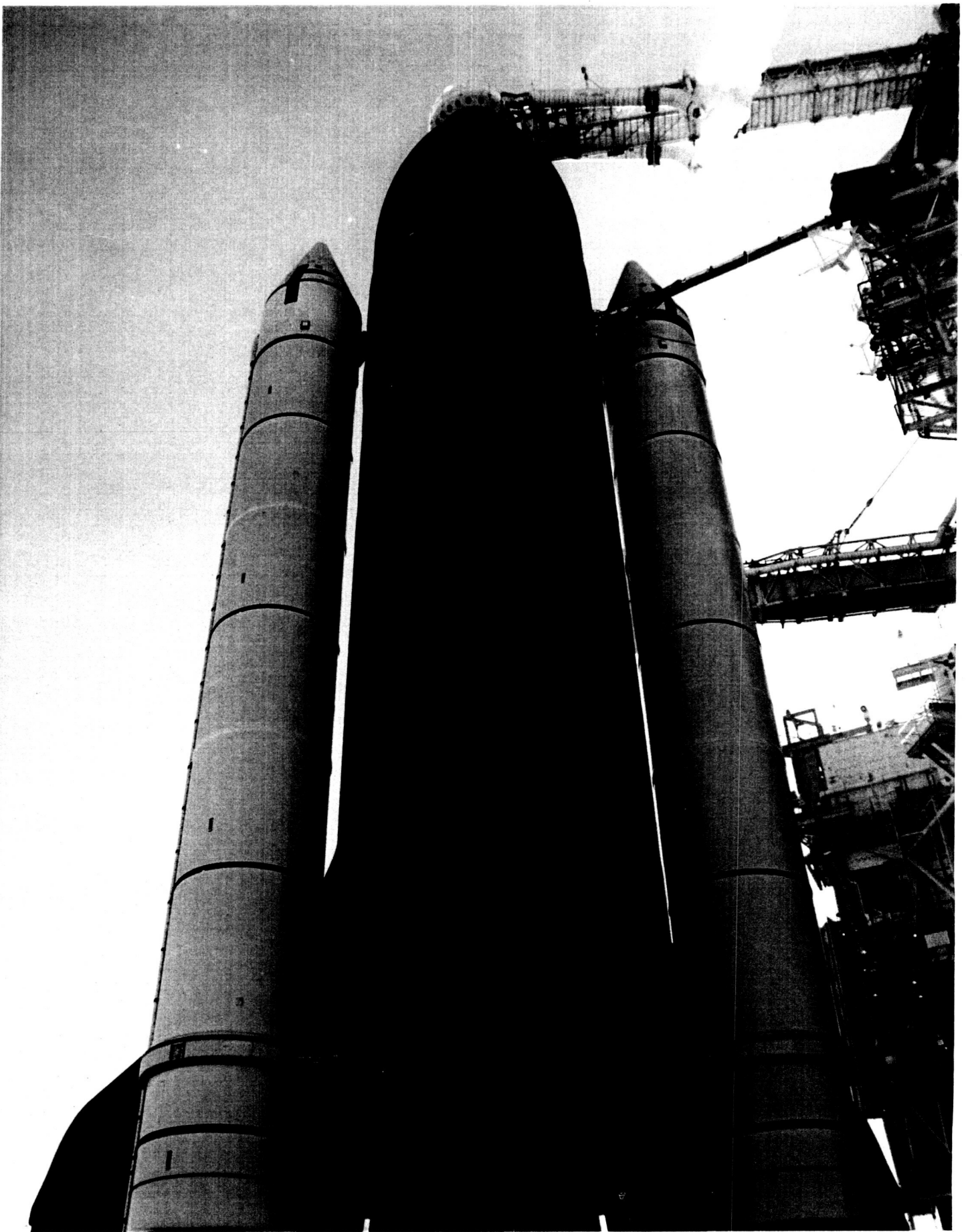
4.5 FACILITY OBSERVATIONS

One new debris concern was identified during the ice/frost inspection of the vehicle. An electrical connector cap on the east side of the LO2 TSM was loose and hanging from a retainer chain. The cap was re-attached and tightened. No leaks were observed on either the LO2 or LH2 ORB T-0 umbilicals, though condensate run-off dripped from the LH2 umbilical. There was also no apparent leakage anywhere on the GH2 vent line or GUCP. The modification to the GH2 vent line prevented ice from forming but some ice/frost, which was expected, had accumulated on the GUCP legs. The GOX duct seals were fully inflated and seated. Visual and infrared observations of the GOX seals confirmed no leakage. There were no icicles on the GOX vent ducts.

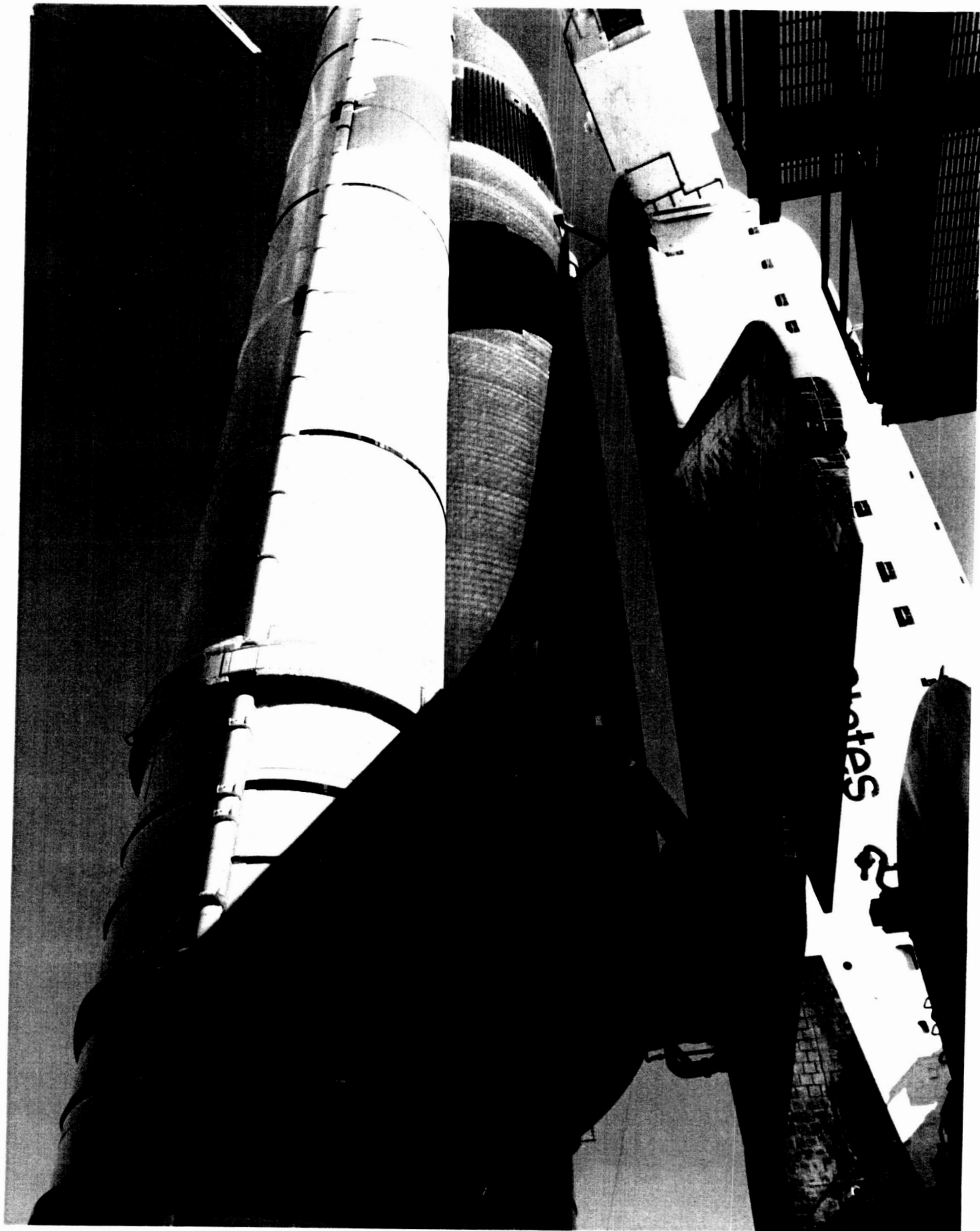
The third water trough (5th from the SRB nozzle) in the secondary sound suppression group had leaked and was nearly empty. Review/analysis/discussion by the launch team and Mission Management Team determined this condition was acceptable for launch.



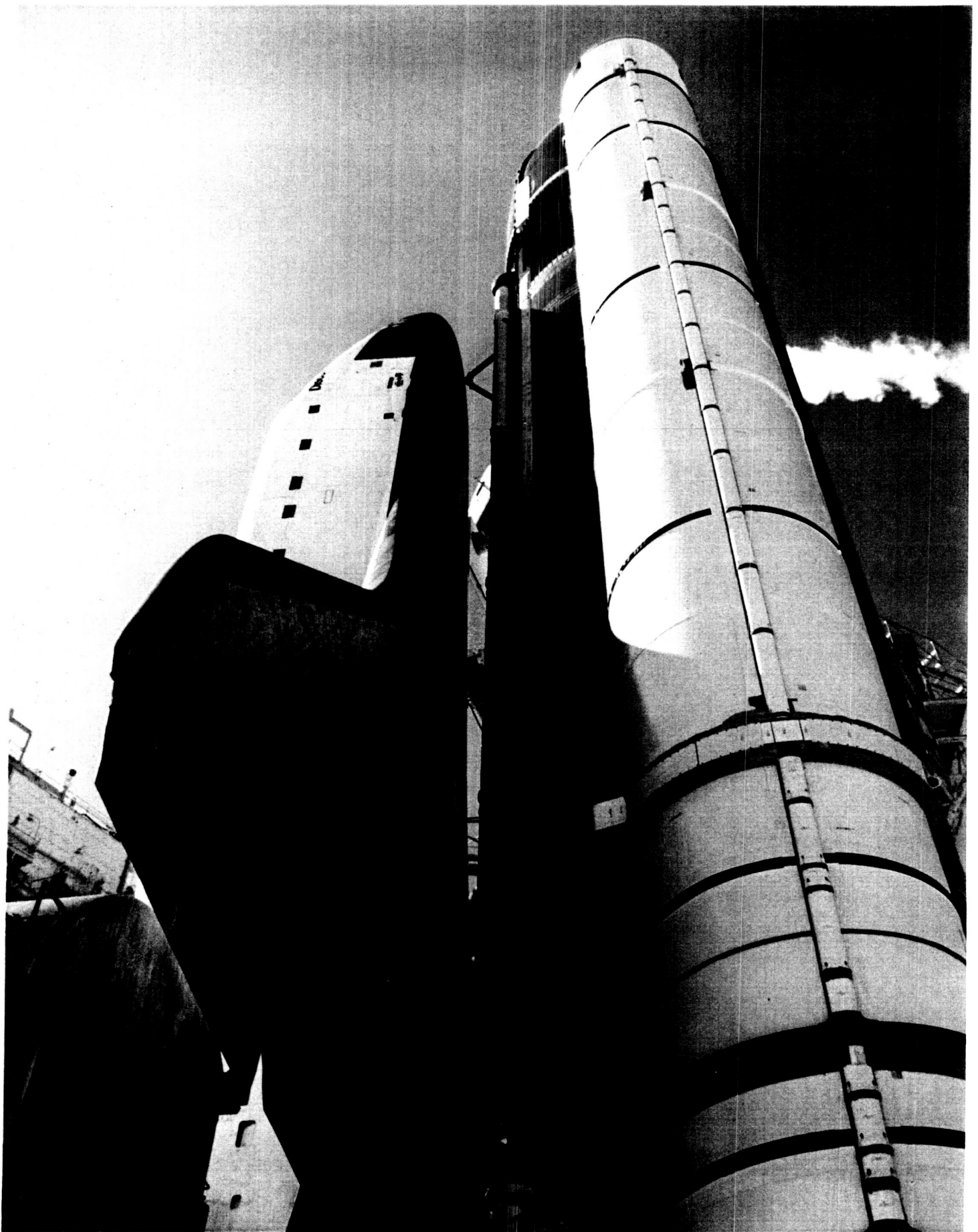
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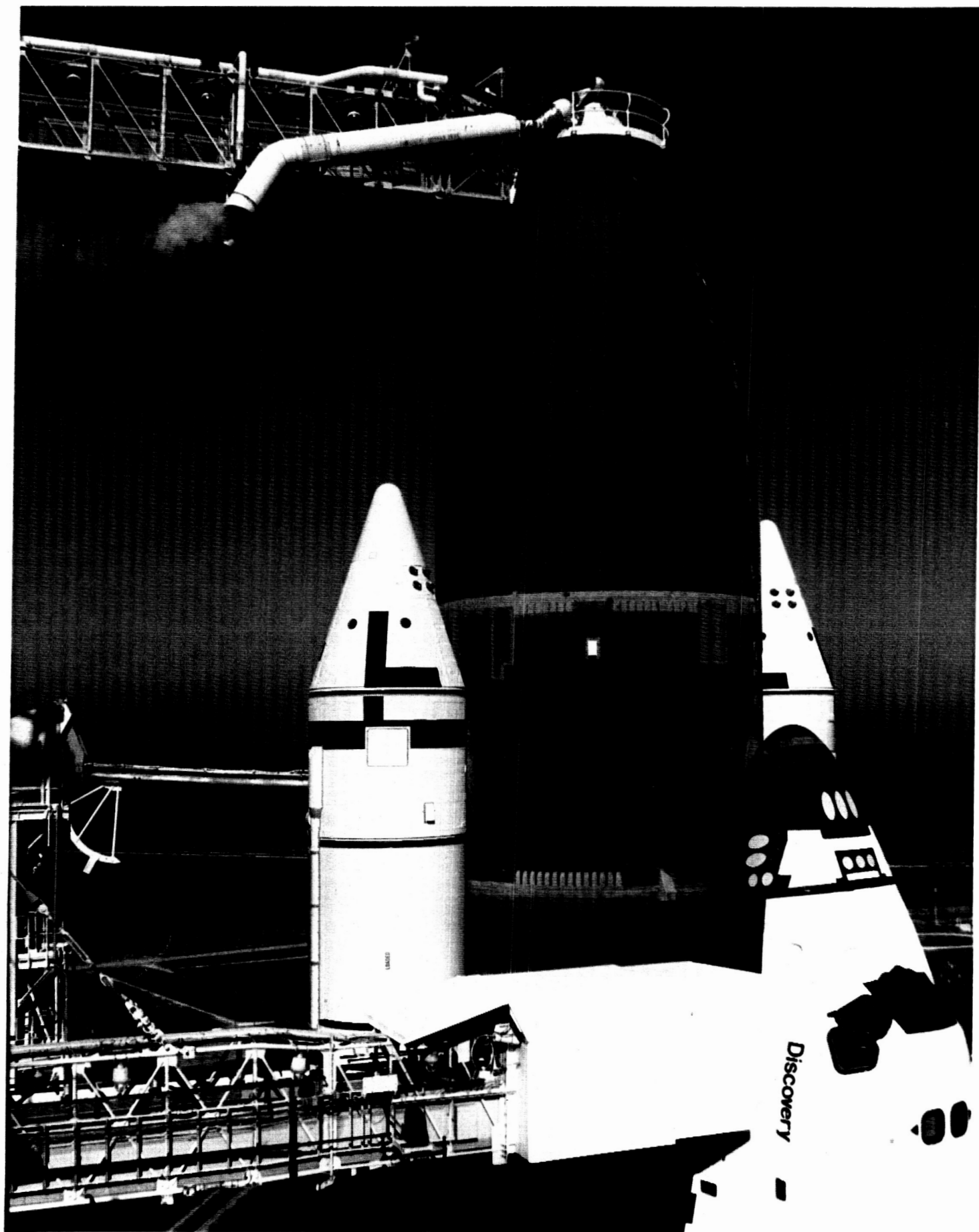
Overall view of SRB's and External Tank -Z side acreage
Note southerly wind blowing GOX vapors well away from vehicle



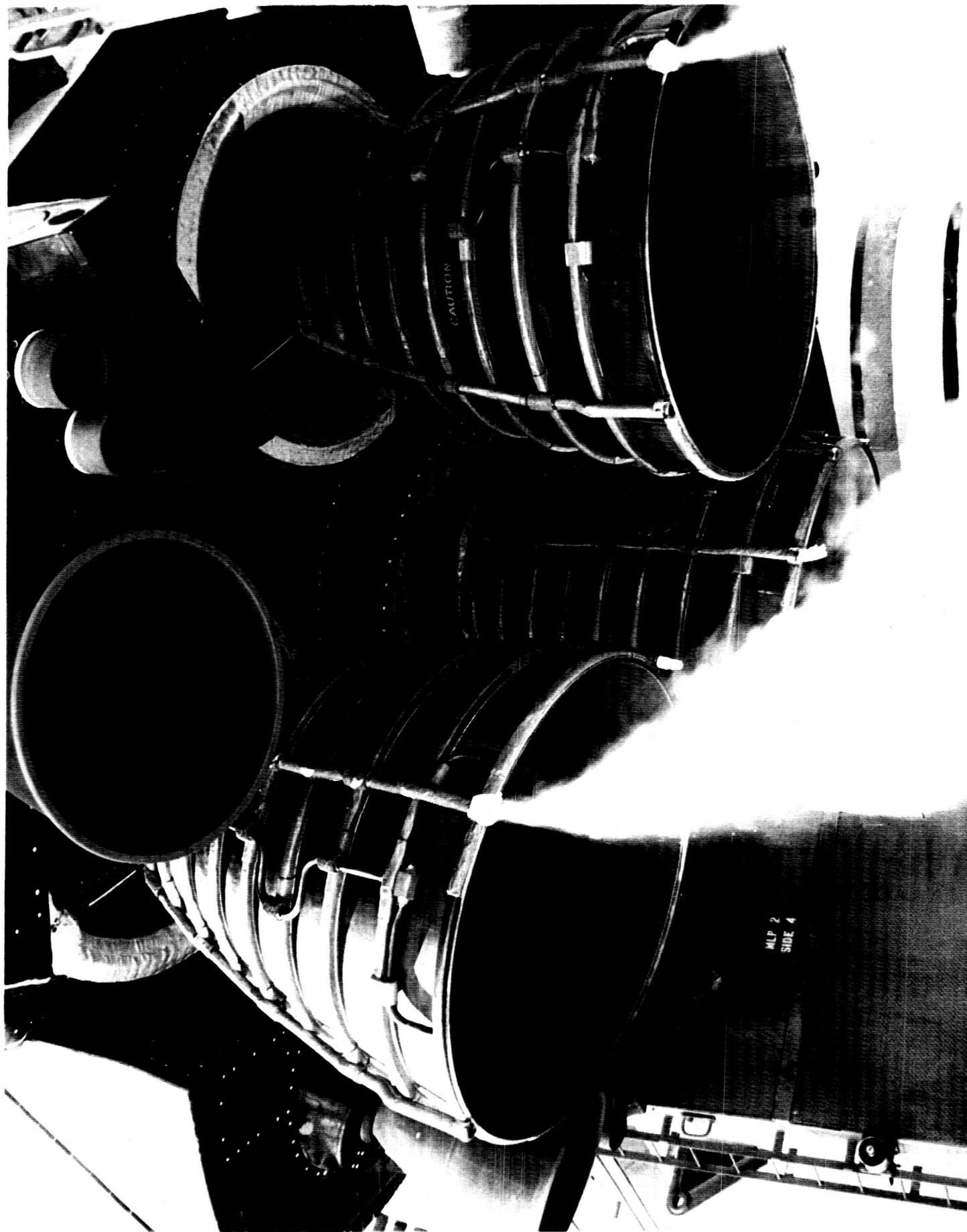
Overall view of vehicle -Y side. No ice or frost had accumulated on the ET acreage



Overall view of vehicle +Y side. No ice or frost had accumulated on the ET acreage



Condensate was light with no ice/frost on the ET L02 tank.
Note GOX vapors blown well away from vehicle by southerly winds



Overall view of Space Shuttle Main Engines. Frost had accumulated on the SSME #2 engine mounted heat shield interface



Frost had accumulated on the SSME #1 engine mounted heat shield at the 6 o'clock position



Frost and condensate were present on the SSME #2 engine mounted
heat shield interface

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Light frost spots on the ET LH2 tank aft dome apex and
manhole cover, which are acceptable per NSTS-08303



Moderate amounts of ice/frost accumulated on the ET/ORB umbilicals. Note release lanyard for hydrogen detector.



The sides of the ET/ORB LH2 umbilical were covered by moderate, but typical, ice/frost. A frost finger formed on the purge vent



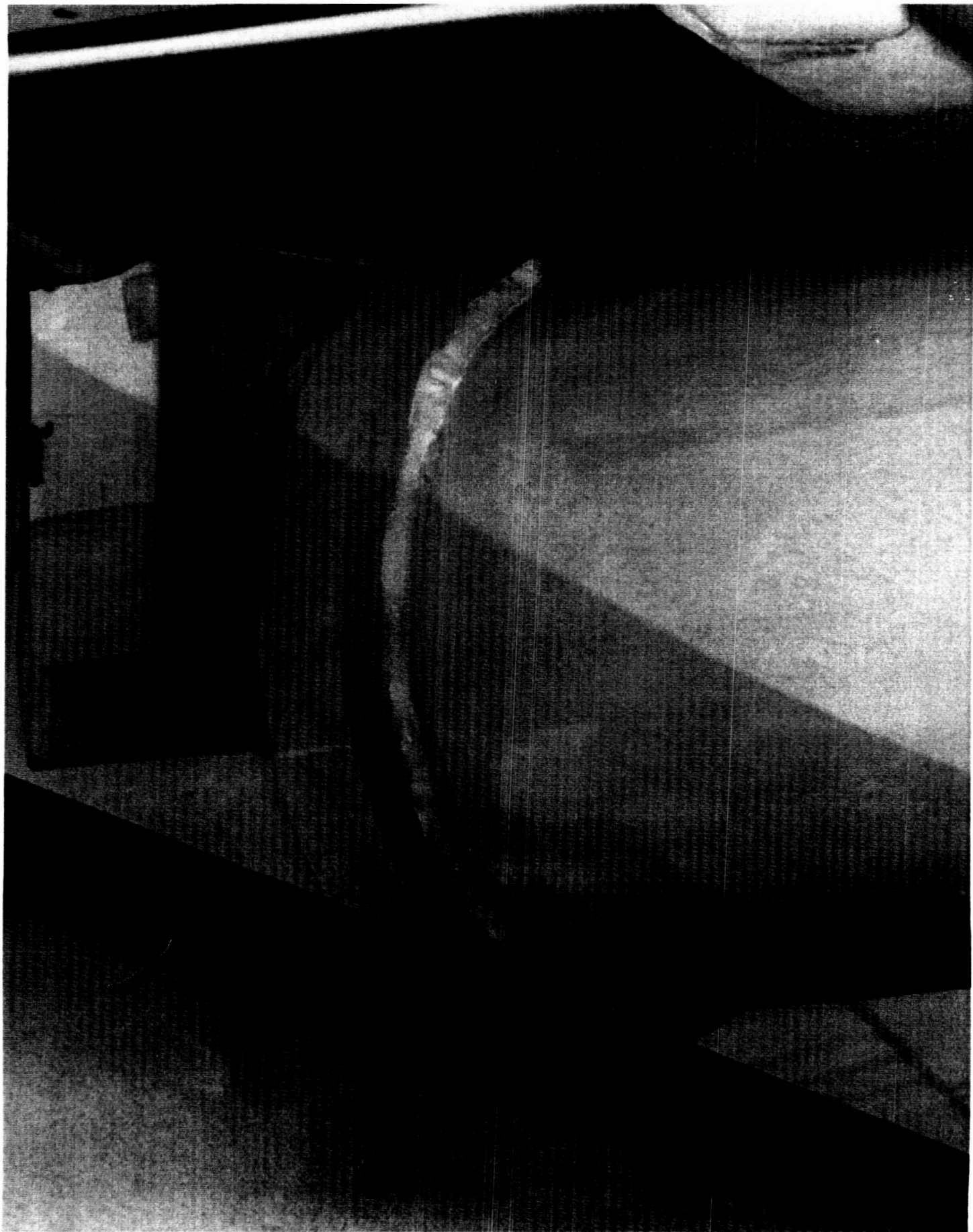
A moderate amount of ice had formed in the LH2 recirculation line bellows, but only condensate appeared in feedline bellows.



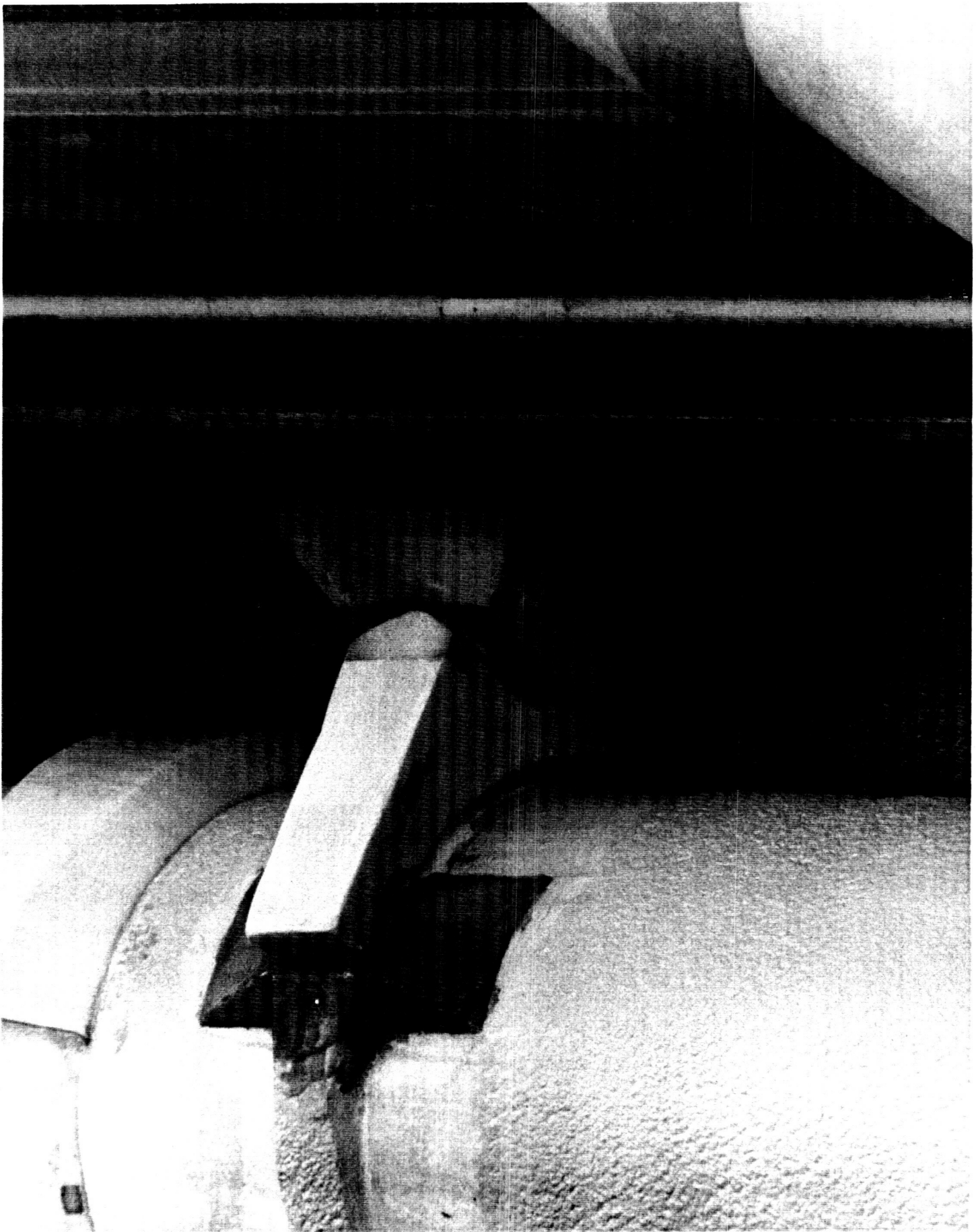
Light, but typical, ice/frost formed on the aft side of the ET/ORB LO2 umbilical. Frost fingers formed on the purge vents.



Hard ice formed in the lower LO2 feedline bellows.

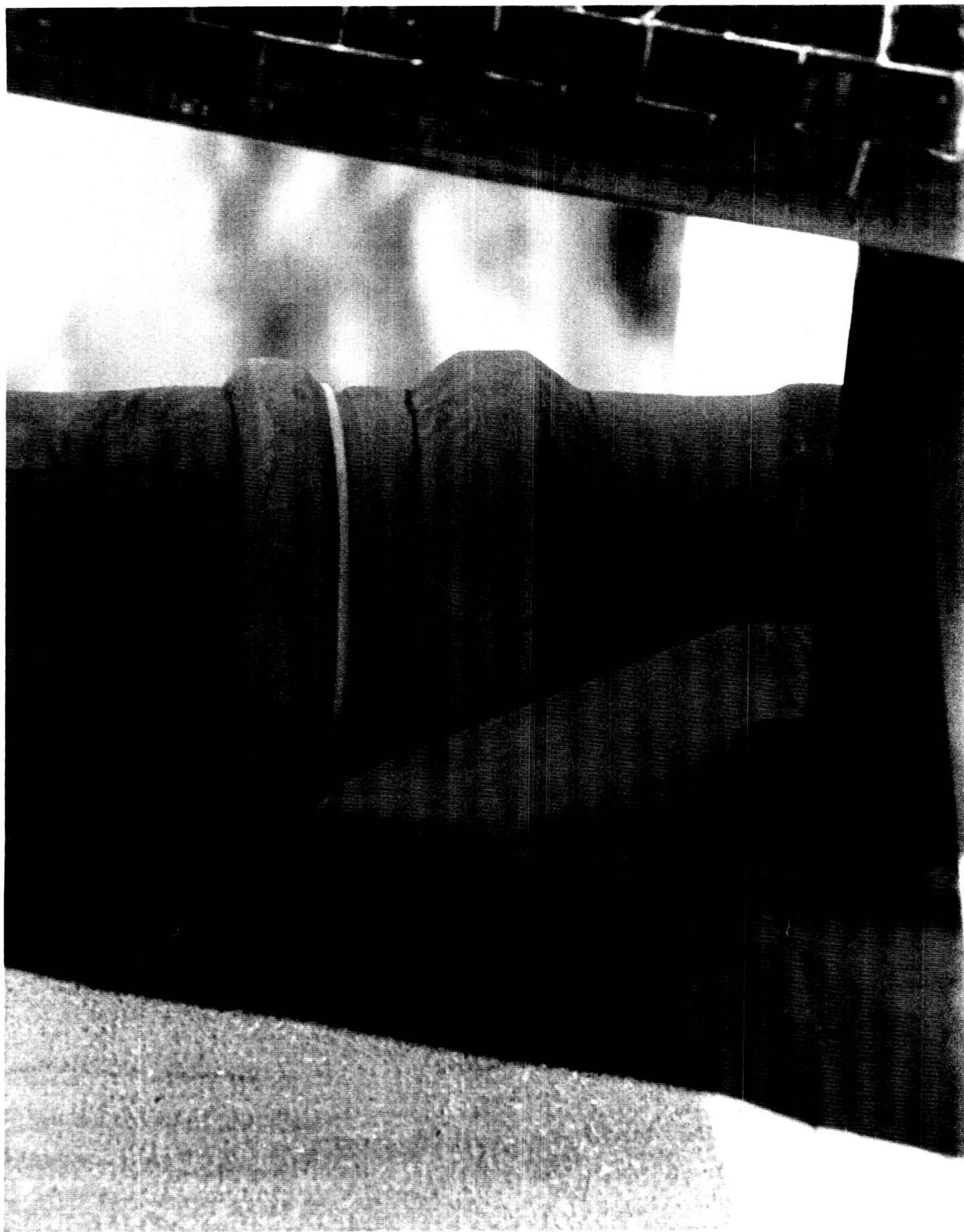


Hard ice formed in the L02 feedline support brackets and lower feedline bellows.



Typical formation of ice/frost in the LO2 feedline
support brackets

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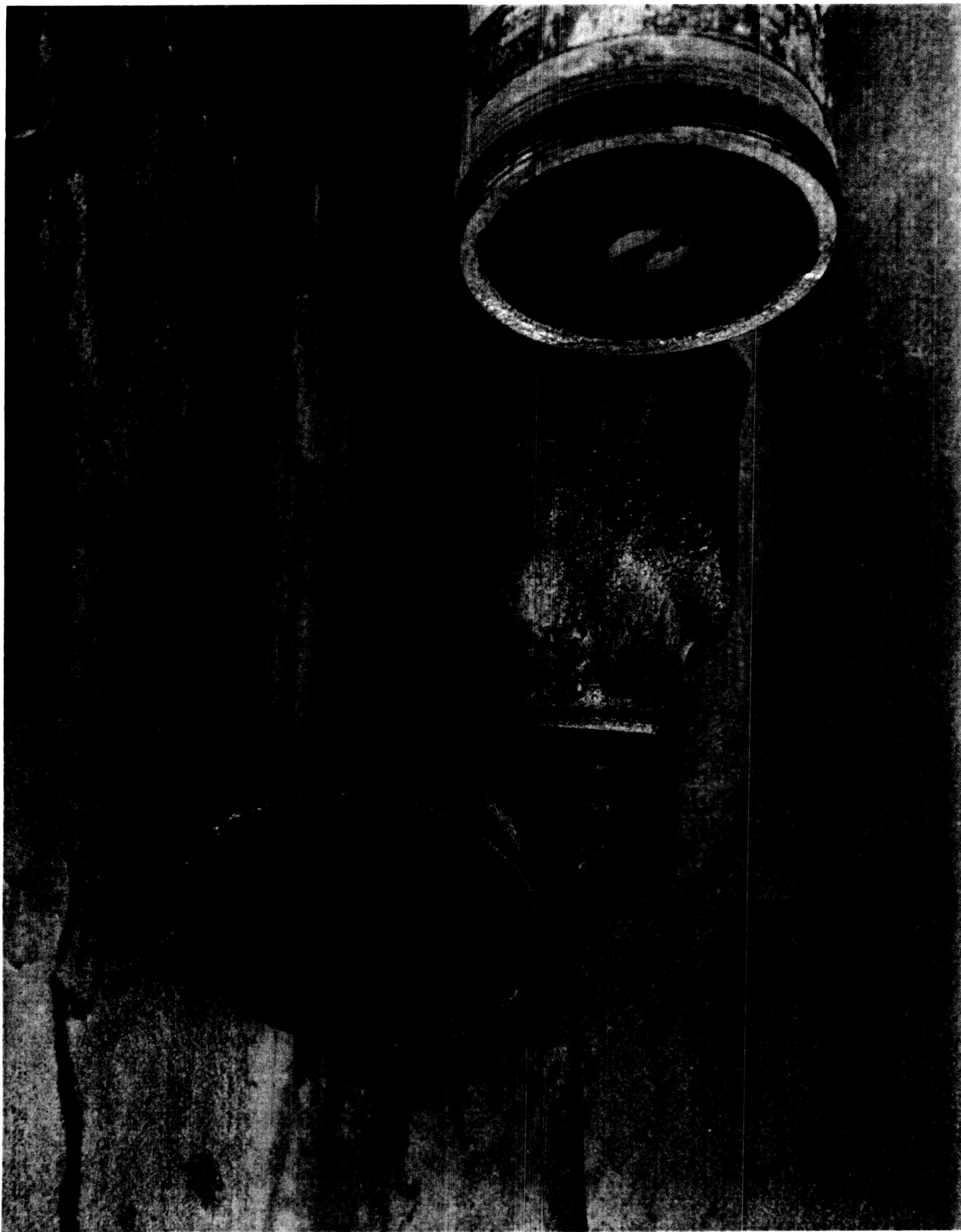
Hard ice and frost had accumulated in the upper LO2
feedline bellows



Ice had formed in the -Y-Z stringer valleys at the
LH2 tank and LO2 tank-to-intertank flanges



The RH SRB secondary sound suppression water trough
(5th from the SRB nozzle) had leaked and was nearly empty



Loose electrical connector cap on the L02 TSM east side
was re-attached and tightened prior to launch

5.0 POST LAUNCH PAD DEBRIS INSPECTION

The post launch inspection of the pad and surrounding area began on 22 November 1989 from launch + 2.5 through 4 hours. The MLP, FSS, and pad apron were inspected the day of launch. Because of darkness, inspection of the pad acreage areas began the next day. Completion of the pad acreage areas, as well as inspection of the beach road, railroad tracks, beach, and ocean area under the flight path were accomplished the day after Thanksgiving. No significant flight hardware or TPS materials were found with the exception of 3 Q-felt closeout plugs from the Orbiter base heat shield tiles. These plugs were recovered south and east of the pad apron near the crawlerway. The shim material that fell from the RH SRB aft skirt HDP #3 foot (seen in the film review) was not located. The usual SRB throat plug material (foam and RTV) and water trough material from the SRB exhaust holes was scattered from the pad apron to the perimeter fence.

SRB holddown post erosion was normal for this launch. South holddown post shim material was intact, but had debonded from the shoe sidewall. Shim material was 50 percent debonded on HDP #2 and #6. No conditions indicative of stud hang-up were visible on HDP #3. All of the doghouse blast covers on the north holddown posts were in the closed position, exhibited no apparent damage, and did not appear to be missing any parts. The SRB aft skirt purge lines were in place and slightly damaged. The SRB joint heater umbilicals showed minor damage after separation.

Typical amounts of facility debris were found. The most significant item was a 3' x 2' aluminum facility cable tray cover. Numerous pieces of gray facility coating material (scale) were found.

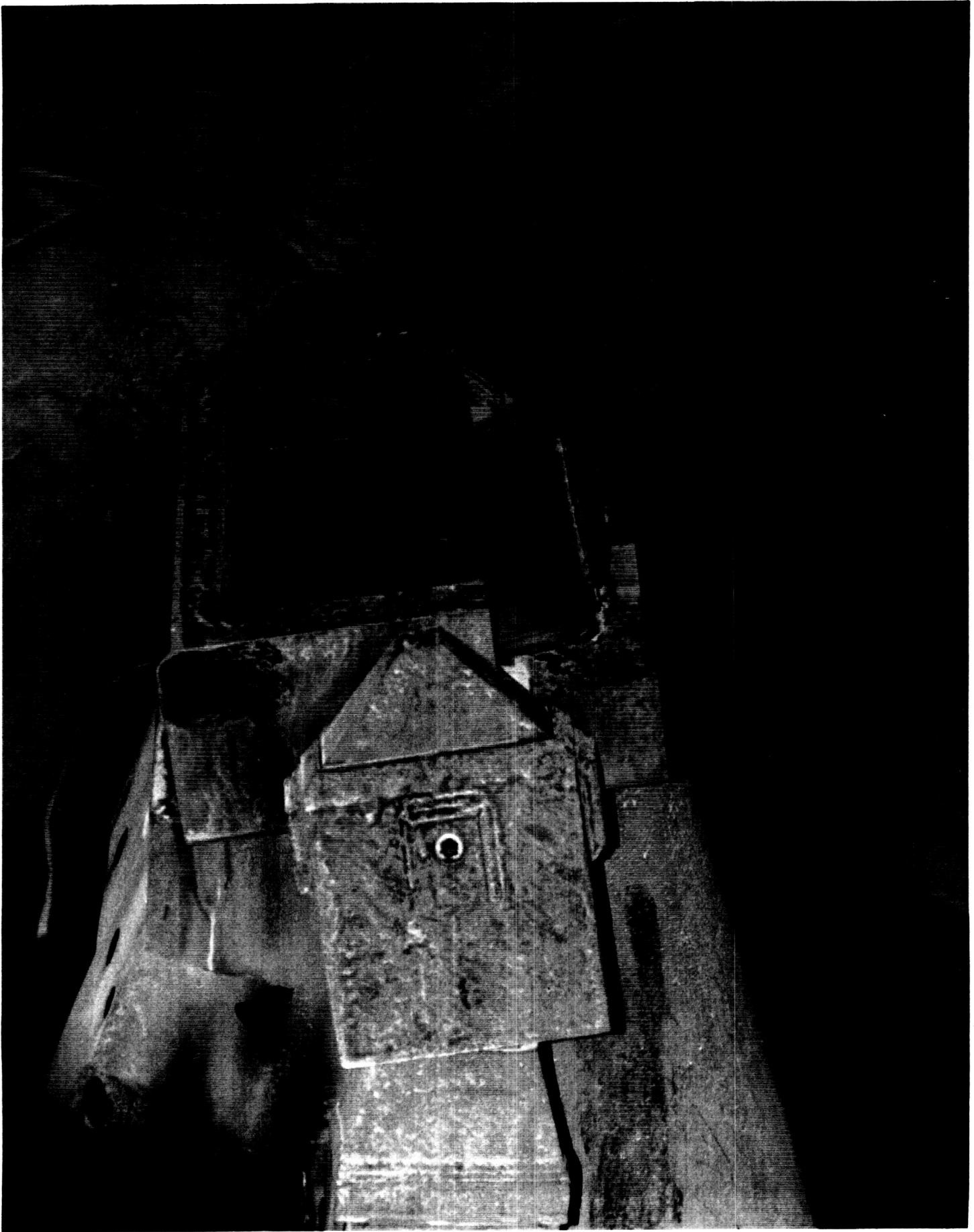
Launch damage to the GOX vent arm, Orbiter access arm, and tail service masts (TSM) was minimal. The GH2 vent arm was latched on the eighth tooth of the latching mechanism and no loose cables dangled from the haunch. However, the GH2 vent arm retract cable was wrapped around the swivel housing assembly on the GUCP causing damage to the 7-inch QD sealing surface and breaking an electrical connector. The following PR's were written on the GH2 vent arm and GUCP as a result of this problem: PR U78-0102-00-002-0149, S78-0220-00-002-0021, 0022, 0023.

All seven emergency egress slidewire baskets were secured on the FSS 195 foot level and sustained no launch damage.

Overall, there was very little damage to the launch pad.

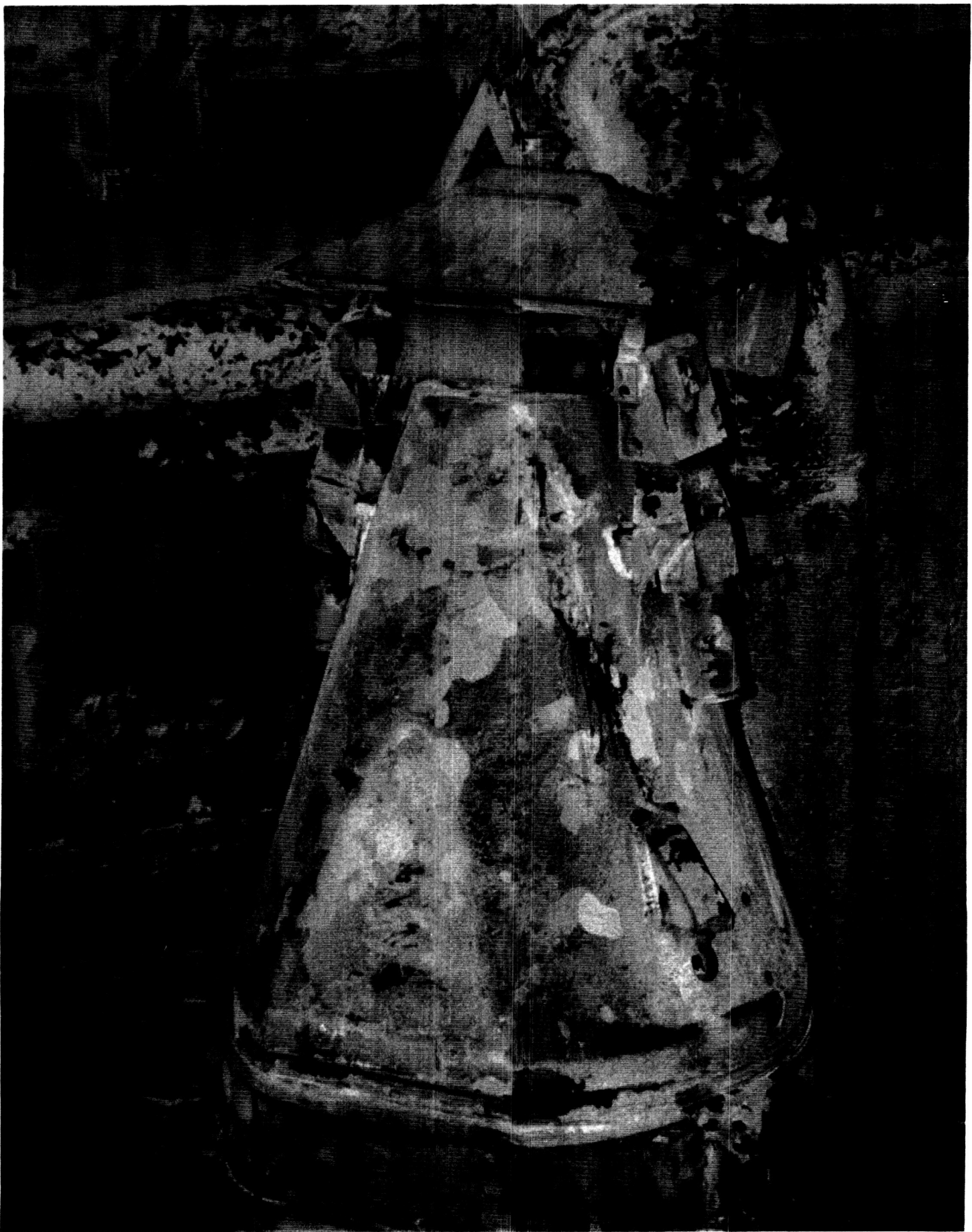
Patrick AFB and MILA radars had been configured again in a mode for increased sensitivity for the purpose of observing any debris falling from the vehicle during ascent. Although the signals were very weak, a total of 23 particles were imaged in the 146-279 second time frame. The most dense group occurred during the period 146-170 seconds, followed by 1 particle every 5 seconds after 170 seconds. This compares to 30 particles during the same time period for the STS-28R flight.

The debris inspection continued on 23 November 1989 and was expanded to include areas outside the perimeter fence. Ground teams searched the beach, railroad tracks, and beach access road from the northern KSC boundary to the Titan complex. The NASA helicopter was utilized to cover the water areas around the pad, the beach from the Cape lighthouse to a point 10 miles north of the pad, and the ocean area under the flight path. No flight hardware was found.

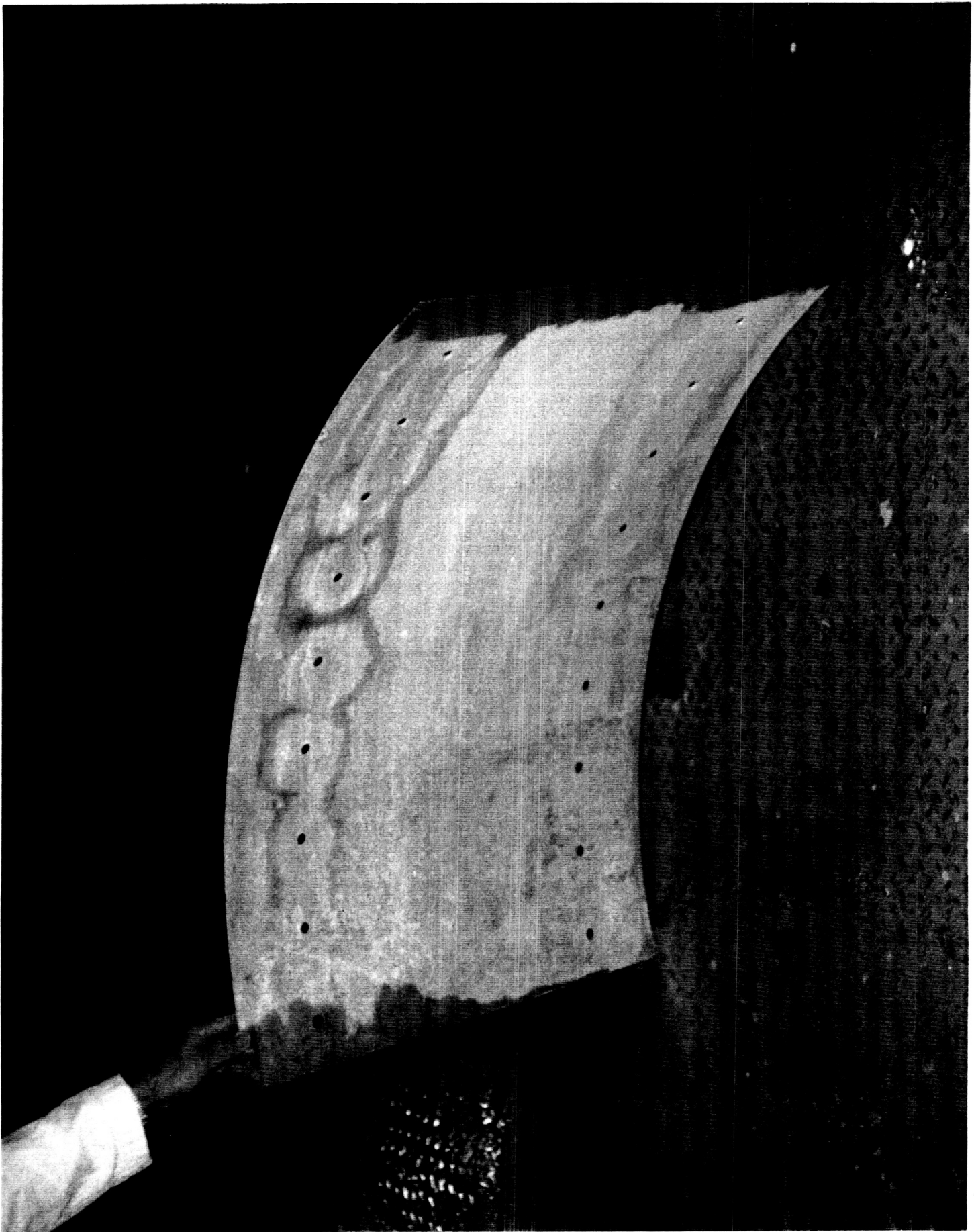


EA 934 shim material on the south holddown posts had debonded
from the holddown post shoes

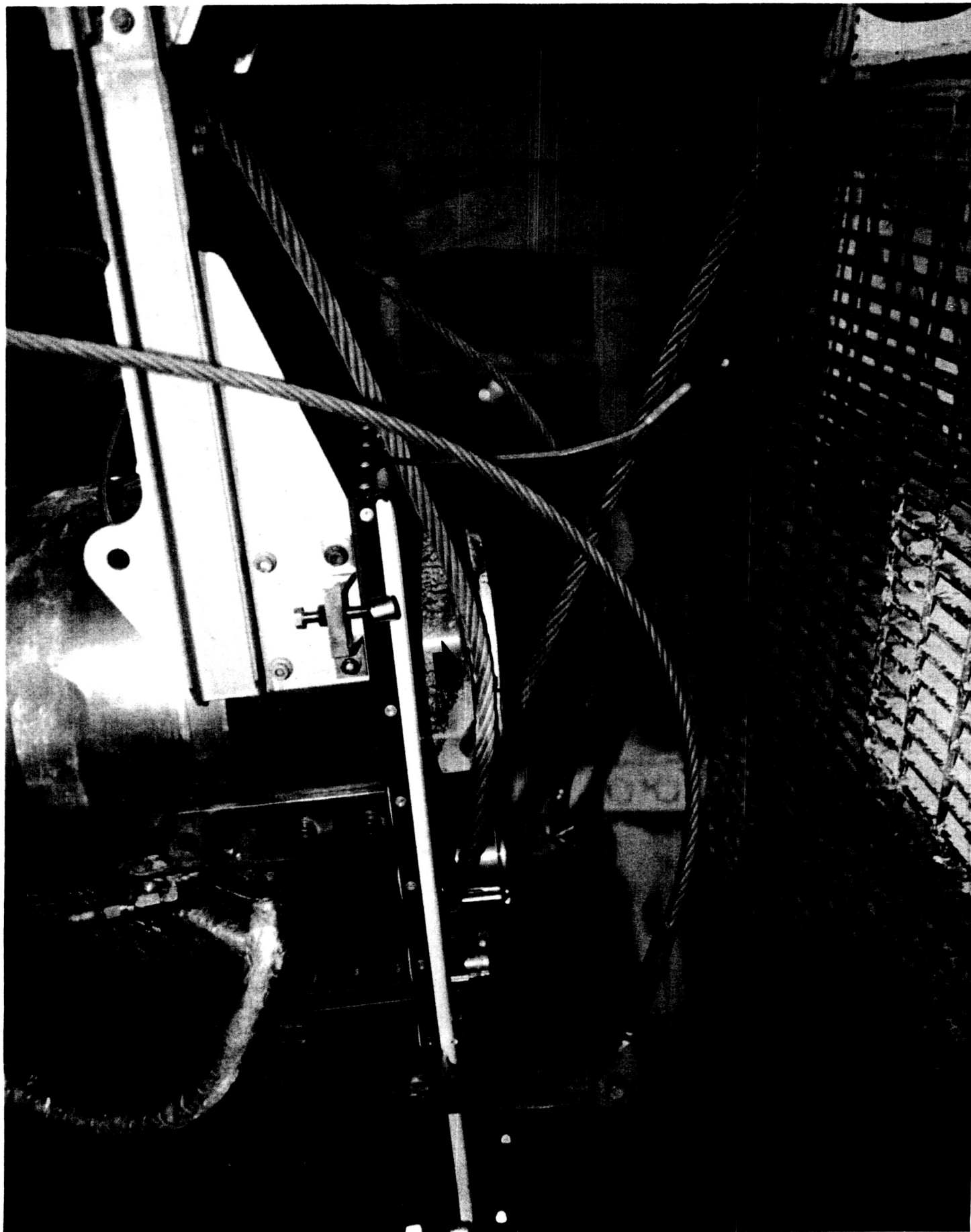
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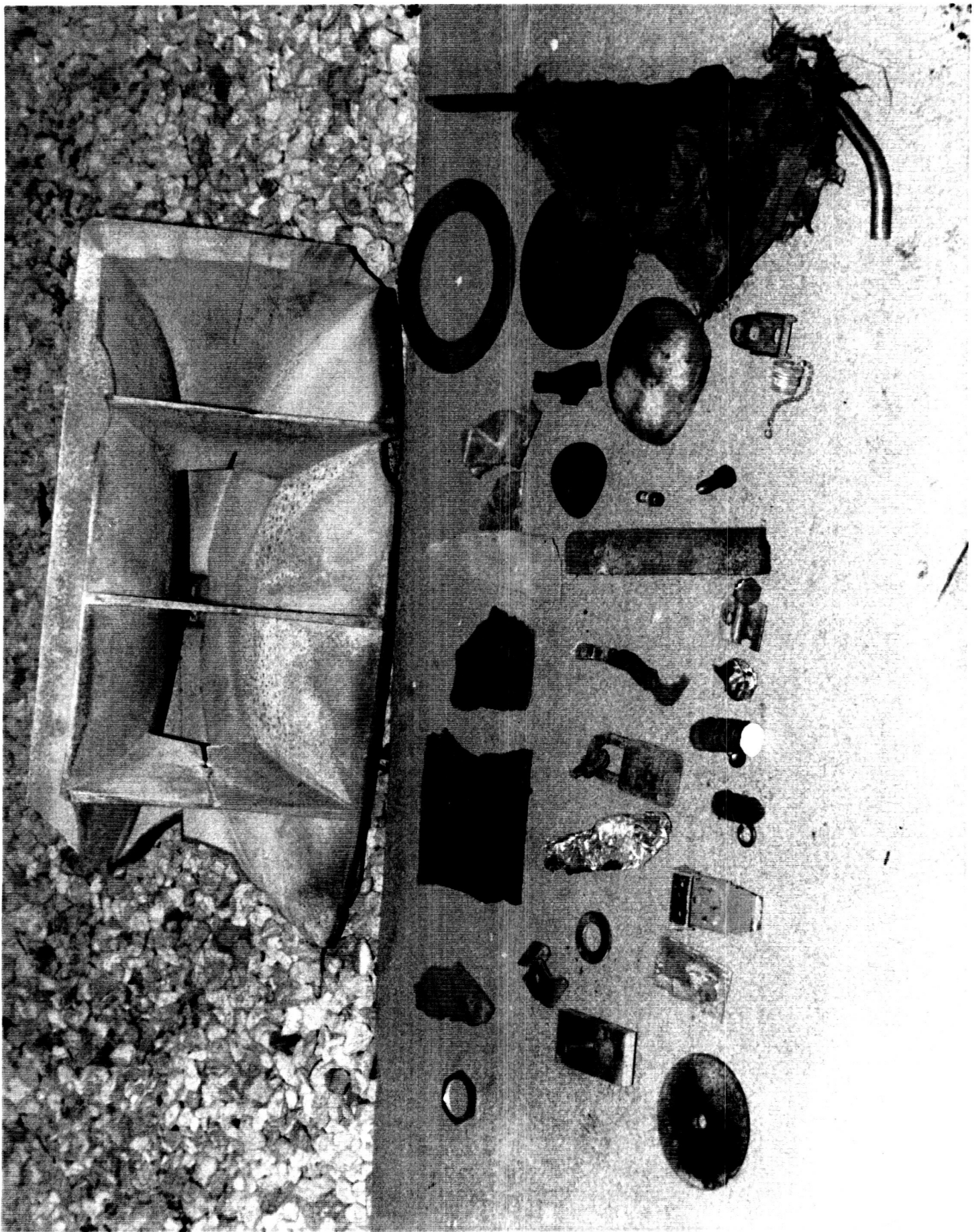
All HDP doghouse blast covers had closed properly. Erosion on
the north holddown posts was minimal.



A 3'x2' aluminum facility cable tray cover was found
on the RSS 140 foot level



The GH2 vent arm retract lanyard wrapped around the swivel housing and damaged the 7-inch QD sealing surface



Typical debris recovered after launch. Q-felt plugs from the
Orbiter base heat shield area are usually found.

6.0 FILM REVIEW SUMMARY/PROBLEM REPORT DISPOSITION

A total of 129 film and video data items, which included 51 16mm films, 28 35mm films, 7 70mm films, 0 special films, and 43 videos were reviewed starting on launch day.

No major vehicle damage or lost flight hardware was observed that would have affected the mission. However, a stud 'hang-up' occurred on holddown post #3. The momentary drag caused by this condition was detected in the Orbiter yaw accelerometer data. As the vehicle separated from the holddown post shoe, film items E-10, 15, and 27 show the stud still extended (maximum of 10.07 inches) as the aft skirt foot cleared the HDP doghouse blast cover (Figure 6). The stud contacted the aft skirt stud hole wall (bore) and loosened a piece of shim material bonded to the aft skirt foot. The piece of shim, which included the inboard sidewall and a cutout for the stud, fell from the aft skirt foot and disappeared into the SRB exhaust hole. The stud rocked back and forth before dropping into the holddown post sand box.

Free burning hydrogen was blown north by the wind under the body flap and into the area between the SRB aft skirts. Although some of the burning hydrogen was drawn back into the SSME plume by aspiration, some of the hydrogen rose high enough to be consumed and dissipate (E-30, 53, 61, OTV 163). The dynamics of the burning hydrogen was collaborated by the C/S-2 IR data.

SSME ignition acoustics and vibration caused a cluster of five small pieces of tile surface coating material to fall from the base heat shield area near SSME #3 (E-17, 23, 24). Other surface dings near the edge of the heat shield and in the area between SSME #1 and #2 were caused by the same phenomenon.

A heavy shower of ice and frost particles from the ET/ORB LH2 and LO2 umbilicals fell past the body flap during SSME ignition, but no Orbiter tile damage was visible.

Film item E-25 documented numerous particles of debris, some measuring 5 inches in length, moving upward from the SRB exhaust holes at high velocities. Some of these particles, which appeared to have a mass greater than foam, came close to impacting the vehicle.

There were no major facility anomalies. No swing arms or other pad structures contacted the vehicle during liftoff. The GH2 vent arm disconnected, retracted, and swung down to the latched position in a normal manner (E-33, 35, 39, 41, 42, 48, 50). However, excessive slack remained in the retract lanyard which allowed the cable to wrap around the GUCP swivel housing.

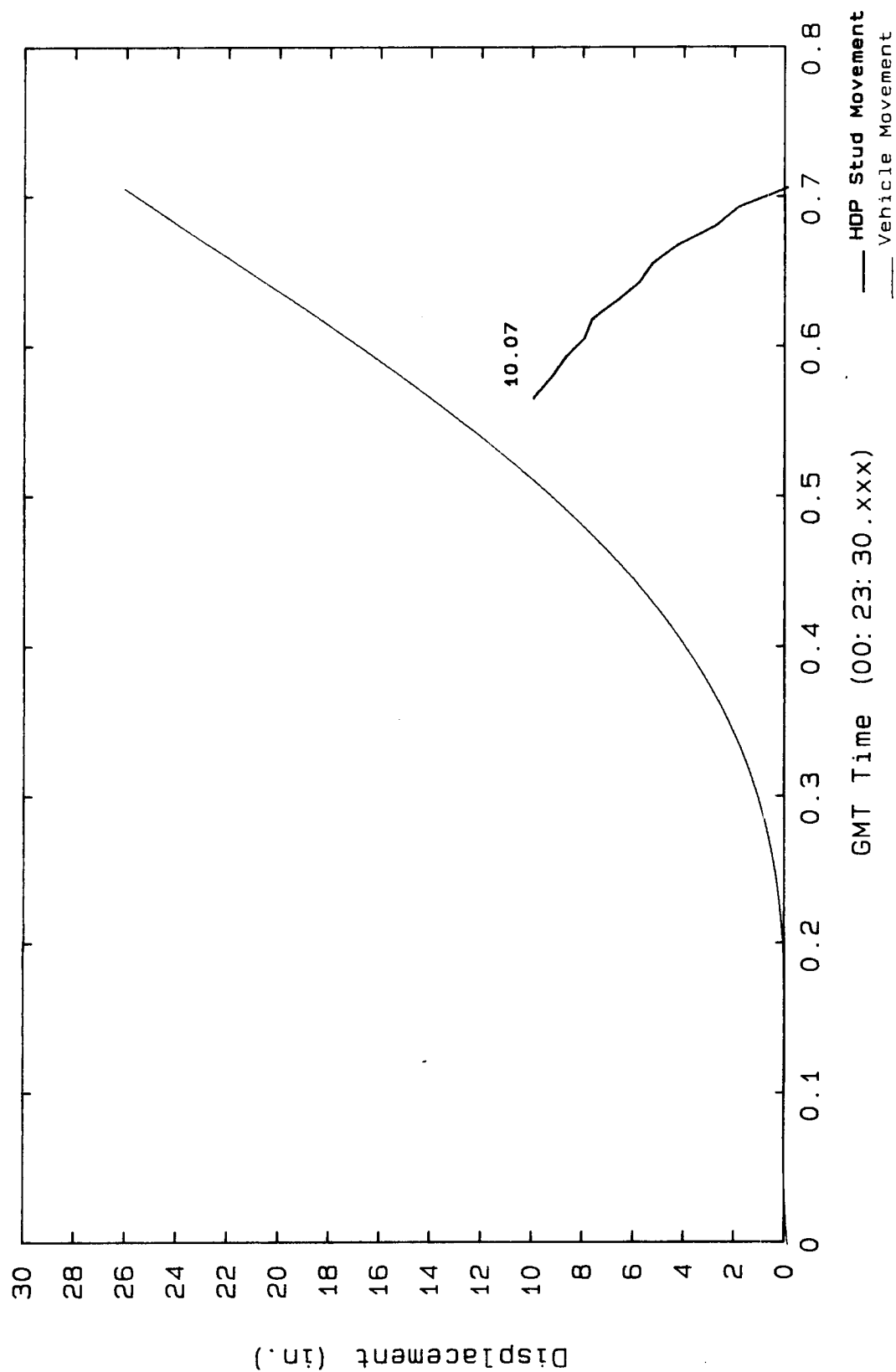


Figure 6. HDP #3 Motion Analysis

The nearly-empty secondary sound suppression water trough was blown upward by the SRB ignition over pressure wave, reached the maximum extension of the tie down cords, and then flapped in the air flow (E-15, 27). No adverse effects on the vehicle were caused by the absence of water in this trough.

Many film and video items recorded various amounts of flying debris on the pad after the vehicle cleared the tower. This debris is SRB throat plug material and shredded sound suppression water troughs - an expected occurrence. Several birds are visible in many of the film items, but none are near the vehicle (E-60, 61).

Water run-off and condensate streamed from the rudder/speed brake split during early ascent (E-53, 57, 60). This is a normal occurrence and has been documented by KSC on previous vehicles.

Movement of the Orbiter body flap was visible after the roll maneuver and through most of the ascent (E-207, 212, 213, 220, 222). The motion appeared to have an amplitude and frequency similar to that observed on previous vehicles.

Numerous pieces of debris from the vehicle were visible during ascent. Most have been identified as ice/frost particles from the ET/ORB umbilicals and RCS paper covers from the Orbiter (E-201, 204, 207). Shortly after the roll maneuver, a large particle near the SSME plume aft of the vehicle can be traced to the LH SRB ETA ring area (E-53). The particles falling from the vehicle after Max Q are either pieces of SRB propellant/inhibitor or SRB aft skirt instafoam. At GMT 24:30.6 (T+60 seconds), a piece of rope-like debris falling from the aft end of the vehicle had been reported by other Centers. KSC timed the object on 6 film items providing a consistent data base. The object looked like a dot in some film items, like a streak in others. It appeared to drop out of the RH SRB plume or become visible around the aft skirt area (as seen from the ground). Since the southern cameras, which had a clear view of the Orbiter aft end, recorded no objects during this time, it seems likely the object originated from the SRB aft skirt area. The object was a piece of burning SRB propellant and/or inhibitor. The 'clinkers' in the SRB plumes (more than 100) prior to and just after separation from the External Tank are chunks of SRB propellant slag.

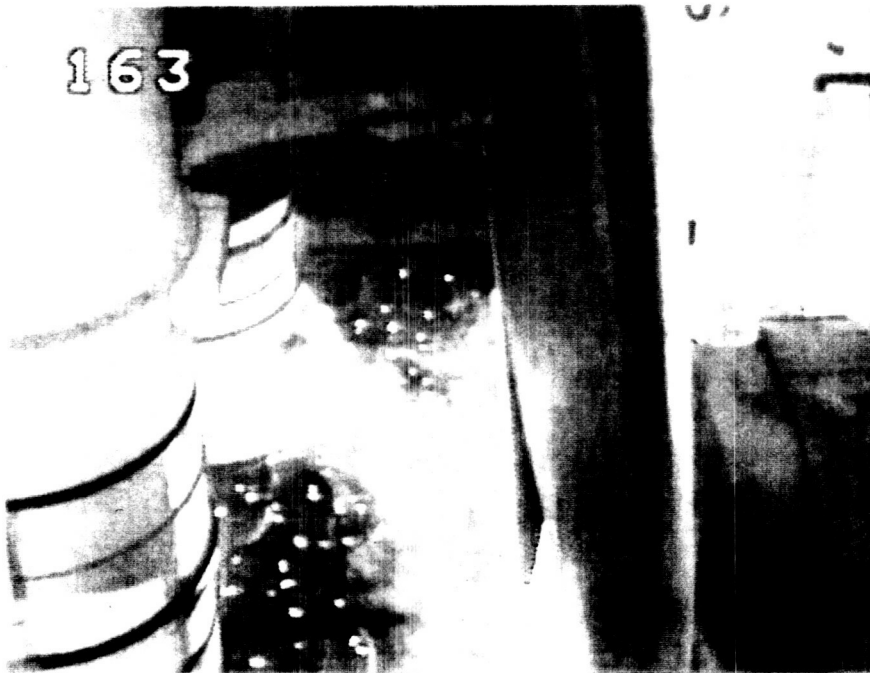
LH MLG door opened and LH MLG wheel extended ahead of the right side similar to previous orbiters. There were no unusual control surface oscillations prior to or after landing. LH MLG touched down slightly ahead of the RH MLG. Nose gear touchdown was smooth, though the strut flexed slightly fore-to-aft.

No PR's or IPR's were generated as a result of the film and video data review. However, the Post Launch Anomalies observed in the Film Review were presented to the Mission Management Team, Shuttle managers, and vehicle systems engineers. These anomalies are listed in Section 10.2.

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TV-7 shows free burning hydrogen blown north under the
Orbiter body flap during SSME ignition



OTV 163 recorded ROFI sparks and free burning hydrogen
blown north under the body flap by southerly winds

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BLACK AND WHITE PHOTOGRAPH

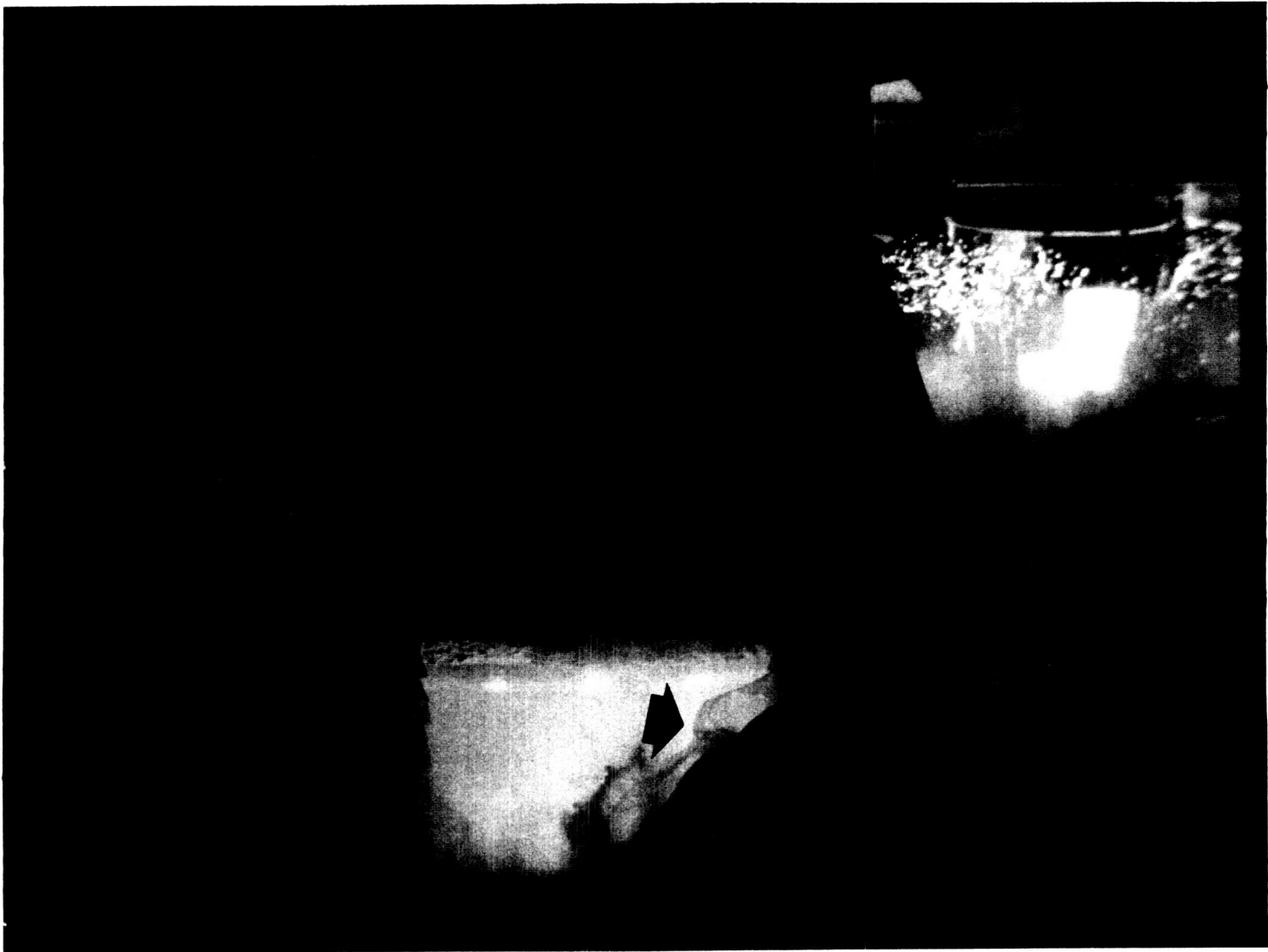


Free burning hydrogen blown north under Orbiter body flap
is visible on OTV 141 at Camera Site #2



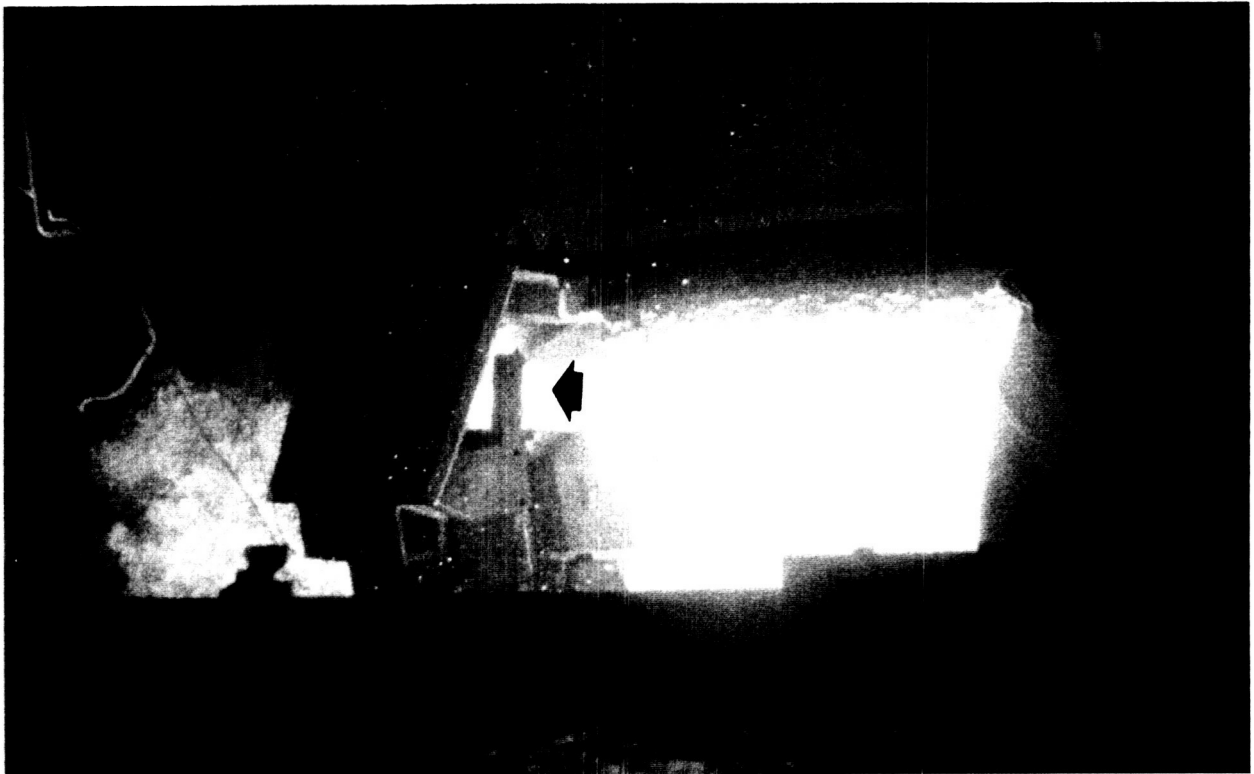
Shuttle Thermal Imager at Camera Site #2 provided infrared
images of free burning hydrogen blown north under body flap

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COLOR PHOTOGRAPH



The nearly empty secondary sound suppression water trough was
blown upward by the RH SRB ignition overpressure wave

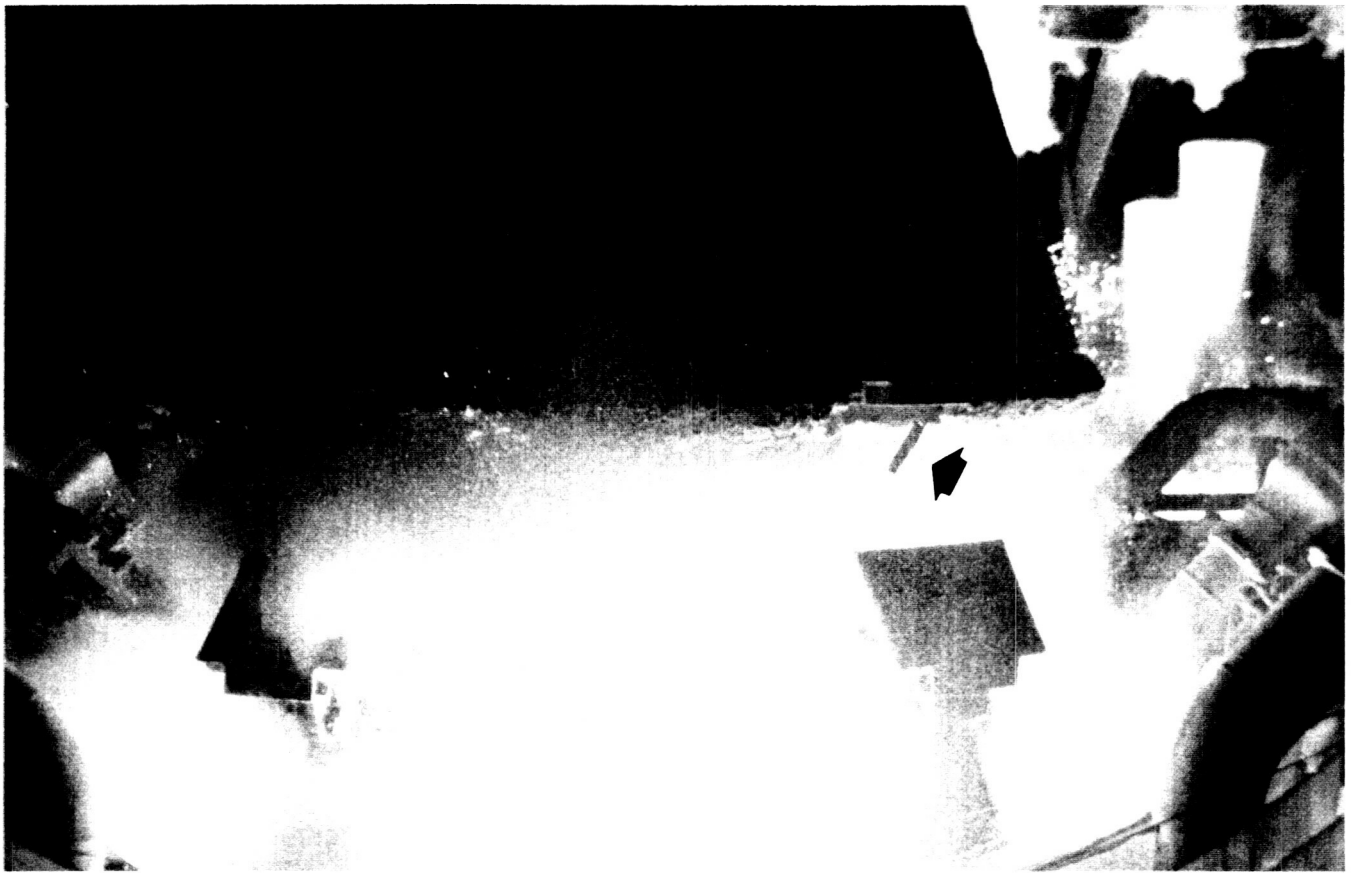
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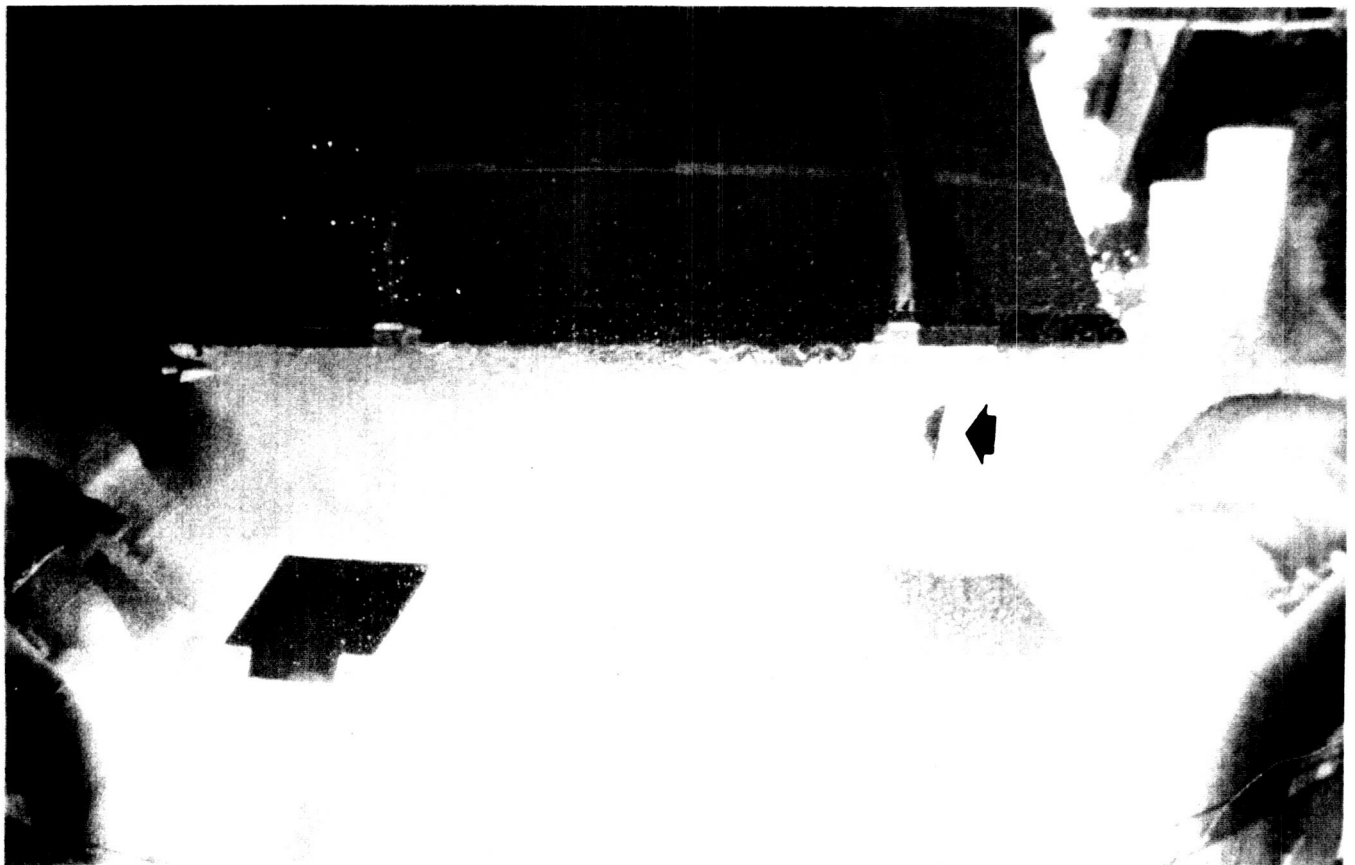
Hung-up stud on HDP #3 extended 10.07 inches as the RH SRB
aft skirt foot cleared the HDP doghouse blast cover



Part of the shim bonded to the aft skirt foot was loosened by
the hung-up stud (HDF 3) and eventually fell from the vehicle



Part of the shim, which was loosened by the stud hang-up on HDP #3, falls from the aft skirt shortly after liftoff



As the piece of shim falls from the vehicle, sidewall material and the cutout for the stud become visible

6.1 LAUNCH FILM AND VIDEO DATA REVIEW

EX1 Camera is located on MLP deck south of RH SRB
400 FPS exhaust duct and looks north to view RH SRB Heater
16mm Umbilical during ignition and liftoff.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: SPARKS FROM THE IGNITERS ARE BLOWN NORTH AND CONTACT RH SRB AFT SKIRT. SIMILARLY, FREE BURNING HYDROGEN IS BLOWN NORTH AND ENTERS FOV. T-0 OCCURS AFTER FRAME 4166 AND THE DEBRIS CONTAINMENT ASSEMBLY OSCILLATES TWICE WHEN THE ORDNANCE FIRES. THE HOLDDOWN POST SHOE ROCKS SLIGHTLY AT LIFTOFF. A 3-INCH PIECE OF INSTAFOAM FALLS FROM THE AFT SKIRT NEAR THE CORNER OF THE HDP SHOE AT FRAME 4364. NO DEBRIS FALLS FROM THE AFT SKIRT STUD HOLE AND THERE WERE NO SRB JOINT HEATER UMBILICAL ANOMALIES.

EX2 Camera is located on the MLP deck west of RH SRB
400 FPS flame duct and looks east to view SRB Heater
16mm Umbilical during ignition and liftoff.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: HEAT WAVES FROM THE FREE BURNING HYDROGEN ARE BLOWN NORTH ARE VISIBLE. SMALL PIECES OF FACILITY DEBRIS ARE DRAWN ACROSS THE MLP DECK IN THE DIRECTION OF THE SSME EXHAUST HOLE BY ASPIRATION. T-0 OCCURS AT FRAME 4309. WATER FROM THE PRIMARY SOUND SUPPRESSION WATER TROUGHS GEYSERS UPWARD AND DRIPS OFF OF THE SRB THERMAL CURTAINS. THERE WERE NO ANOMALIES DURING SRB JOINT HEATER UMBILICAL DISCONNECT AND NO PIECES OF INSTAFOAM PULLED LOOSE FROM THE AFT SKIRT.

EX3 Camera is located on the MLP deck east of LH SRB
400 FPS flame duct and looks west to view SRB Heater
16mm Umbilical during ignition and liftoff.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: SMALL PIECES OF FACILITY DEBRIS ARE DRAWN ACROSS THE MLP DECK IN THE DIRECTION OF THE SSME EXHAUST HOLE BY ASPIRATION. T-0 OCCURS AT FRAME 4226. WATER FROM THE PRIMARY SOUND SUPPRES-

SION WATER TROUGHS GEYSERS UPWARD AND DRIPS OFF OF THE SRB THERMAL CURTAINS. THERE WERE NO ANOMALIES DURING SRB JOINT HEATER UMBILICAL DISCONNECT AND NO PIECES OF INSTAFOAM PULLED LOOSE FROM THE AFT SKIRT.

EX4 Camera is located on MLP deck south of LH SRB
400 FPS flame duct and looks north to view LH SRB Heater
16mm Umbilical during ignition and liftoff.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: NO FREE BURNING HYDROGEN FROM SSME IGNITION IS VISIBLE IN THE FOV. HOWEVER, SMALL PIECES OF K5NA CLOSEOUT TRIMMINGS COME FROM BEHIND THE DCA PLUNGER HOUSING DURING SSME IGNITION. T-0 OCCURS AT FRAME 4064. THE DCA OSCILLATES TWICE WHEN THE ORDNANCE FIRES. THE HOLDDOWN POST SHOE ROCKS SLIGHTLY AT LIFTOFF. NO DEBRIS FALLS OUT OF THE SRB AFT SKIRT STUD HOLE, THOUGH A SMALL FOAM PARTICLE IS VISIBLE BETWEEN THE AFT SKIRT AND THE HDP SHOE. THERE WERE NO SRB JOINT HEATER UMBILICAL ANOMALIES.

E-1 Camera is located on the NE corner of the MLP deck
400 FPS and views the lower ET, SRB's, and Orbiter.
16mm

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: SSME IGNITION OCCURS AT FRAME 2125. A 1 FOOT SQUARE, FLAT OBJECT APPEARS NORTHWEST OF THE LH SRB AND FALLS AFT IN FRAME 4722. A PARTICLE APPEARS IN THE VICINITY OF THE LH WING AT FRAME 4777. HIGH SPEED PARTICLES HEAD NORTH OUT OF RH SRB EXHAUST HOLE FROM AREA OF HDP #4 (FRAME 4785). THE PARTICLES STILL HAVE HIGH VELOCITY AND MOVE UPWARD PAST ET AFT DOME. TWO PARTICLES MOVE AT HIGH VELOCITY (FRAME 4918) BETWEEN ORBITER AND LH SRB. THE PARTICLES, WHICH EXHIBIT A MASS DENSER THAN FOAM, EXITED THE FOV AFTER CROSSING THE LH SRB. A 5-INCH OBJECT FIRST APPEARS IN THE VICINITY OF THE RH SRB AFT SKIRT (FRAME 4991) WHEN THE VEHICLE HAD REACHED AN ALTITUDE OF 25 FEET. THE OBJECT HEADS NORTHWEST AND PASSES NEAR THE LH SRB. THIS PARTICLE IS VISIBLE NEAR THE ET AFT DOME IN FRAME 5029. THE PARTICLE IS VISIBLE FOR 38 FRAMES OR APPROX 0.1 SECONDS. AT A CAMERA FRAME RATE OF 400 FRAMES PER SECOND, THE PARTICLE IS MOVING AT APPROX 300 FEET PER SECOND AND BEHAVES AS IF THE MASS (DENSITY) WERE GREATER THAN THAT OF FOAM. TWO 8-INCH DIAMETER PARTICLES APPEAR NEAR THE LH SRB FORWARD CENTER SEGMENT IN FRAME 5137. THREE LARGE, 1 FOOT

SQUARE, LIGHT DENSITY OBJECTS APPEAR BELOW AND SOUTH OF THE RH WING (FRAME 5582). CONDENSATE ON ET AFT DOME AND WATER FROM SRB STIFFENER RINGS VAPORIZE AS VEHICLE RISES. TYPICAL THROAT PLUG MATERIAL AND SHREDDED WATER TROUGHS CROSS FOV AFTER LIFTOFF.

E-2 Camera is located on the SE corner of the MLP deck
400 FPS and views Orbiter SSME and OMS engine nozzles.
16mm

Comments: CAMERA MALFUNCTION

E-3 Camera is located on the SW corner of the MLP deck
400 FPS and views Orbiter SSME and OMS engine nozzles.
16mm

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: SSME IGNITION OCCURS AT FRAME 1911. TORN RCS PAPER COVERS FALL INTO SSME PLUME. T-0 OCCURS AT FRAME 4287. RESIDUAL LIQUID OXYGEN VAPORIZES AND RESULTING GOX CLOUD IS DRAWN INTO SSME PLUME BY ASPIRATION. LO2 TSM DOOR CLOSURE APPEARS NORMAL WITH ONLY A SMALL REBOUND. WATER FROM SRB STIFFENER RINGS VAPORIZES AFTER LIFTOFF.

E-4 Camera is located on the NW corner of the MLP deck
400 FPS and views lower ET, SRB's, and Orbiter.
16mm

Focus : OK
F. O. V.: OK, THOUGH WATER DELUGE OBSCURES FOV
Exposure: OK

Comments: SSME IGNITION OCCURS AT FRAME 1900. ICE IS SHAKEN LOOSE FROM ET/ORB UMBILICALS. T-0 OCCURS AT FRAME 4354. UMBILICAL ICE IS VISIBLE NEAR LH SRB AFT SKIRT -Y SIDE (FRAME 4675). CONDENSATE ON THE ET AFT DOME VAPORIZES AFTER LIFTOFF.

E-5 Camera is located on the east side of the MLP
400 FPS deck and views the Orbiter RH wing, body flap,
16mm and lower ET/SRB.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: SSME IGNITION OCCURS AT FRAME 1612. ENGINE START UP
CAUSES BODY FLAP AND RH WING INBOARD ELEVON MOTION. ICE FALLS
FROM ET/ORB UMBILICALS, BUT NO TILE DAMAGE IS VISIBLE. A CLUSTER
OF 5 CHIPS, EACH 1 INCH IN DIAMETER, OCCURRED ON BASE HEAT SHIELD
TILES NEAR SSME #3 ONE O'CLOCK POSITION AND WAS CAUSED BY IGNI-
TION ACOUSTICS (FRAME 4777). ICE PARTICLES FALL FROM LO2 T-0
UMBILICAL. RESIDUAL LO2 IN T-0 UMBILICAL VAPORIZES.

E-6 Camera is located on the east side of the MLP deck
200 FPS and views the RH lower Orbiter wing, body flap, ET
16mm lower LOX feedline, and ET/Orbiter umbilical area.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: A LONG FROST FINGER ADHERED TO THE LO2 ET/ORB UMBILI-
CAL OUTBOARD PYRO PURGE VENT, BUT FELL OF AT T-0. SSME IGNITION
CAUSES ELEVON MOTION. ICE FALLS FROM THE LO2 UMBILICAL PAST THE
BODY FLAP, BUT NO TILE DAMAGE IS VISIBLE. CONDENSATE ON THE ET
AFT DOME VAPORIZES AFTER LIFTOFF.

E-7 Camera is located on the MLP deck and views the
400 FPS RH SRB northeast holddown post (HDP #4).
16mm

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: T-0 OCCURS AT FRAME 3900 AND A CONSIDERABLE AMOUNT OF
THROAT PLUG MATERIAL IS EJECTED FROM THE SRB EXHAUST HOLE. A
SOUND SUPPRESSION WATER TROUGH WAS NEARLY EMPTY OF WATER. SRB
IGNITION CAUSES THIS WATER TO GEYSER. BACKFLOW OF THE SRB PLUME
MOMENTARILY BURNS A LOCALIZED AREA OF INSTAFOAM UNDER THE AFT
SKIRT. HDP DOGHOUSE BLAST COVER IS CLOSING AS THE SRB NOZZLE
PASSES. A PARTICLE MOVES THROUGH THE RIGHT FOV AT FRAME 4192.
NUMEROUS HIGH SPEED PARTICLES EXIT FOV AFTER LIFTOFF.

E-8 Camera is located on the MLP deck and views the
400 FPS RH SRB southeast holddown post (HDP #2).
16mm

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: T-0 OCCURS AT FRAME 3224. NO DEBRIS FALLS FROM THE AFT
SKIRT STUD HOLE. TWO INSTAFOAM PARTICLES MOVE THROUGH THE FOV
SHORTLY AFTER LIFTOFF. AN UNIDENTIFIED PARTICLE APPEARS FROM
BEHIND THE SRB IN THE UPPER RH CORNER OF THE FRAME (4561).

E-9 Camera is located on the MLP deck and views the
400 FPS RH SRB southwest holddown post (HDP #1).
16mm

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: IGNITER SPARKS ARE BLOWN NORTHWARD AND SOME IMPACT THE
RH SRB AFT SKIRT. T-0 OCCURS AT FRAME 4068. THERE IS NO EVIDENCE
OF STUD HANG-UP, THE HDP SHOE IS STEADY DURING SEPARATION, AND NO
DEBRIS FALLS FROM THE AFT SKIRT STUD HOLE. SRB THROAT PLUG
MATERIAL IS EJECTED FROM THE EXHAUST HOLE AFTER IGNITION.

E-10 Camera is located on the MLP deck and views the
400 FPS RH SRB northwest holddown post (HDP #3).
16mm

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: T-0 OCCURS AT FRAME 3798. WATER TROUGH MATERIAL AND TIE
DOWN CORD PULL LOOSE AT T-0. THE HDP STUD HANGS-UP, WITH MAXIMUM
STUD EXTENSION OF 10.07 INCHES AT FRAME 3984. AS THE VEHICLE
RISES, THE HDP STUD CONTACTS THE AFT SKIRT STUD HOLE WALLS AND
LOOSENS A PIECE OF SHIM MATERIAL BONDED TO THE AFT SKIRT FOOT.
THE PIECE OF SHIM, WHICH INCLUDES THE INBOARD SIDEWALL AND A
CUTOUT FOR THE STUD, FALLS FROM THE AFT SKIRT FOOT AT FRAME 4126
AND DISAPPEARS INTO THE SRB EXHAUST HOLE.

E-11 Camera is located on the MLP deck and views the
400 FPS LH SRB northeast holddown post (HDP #7).
16mm

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: T-0 OCCURS AT FRAME 4323. LOOSE WATER TROUGH MATERIAL AND TIE DOWN CORD APPEAR IN FOV AT T-0. SEVERAL PIECES OF DEBRIS MOVE THROUGH FRAME AS VEHICLE RISES. HDP DOGHOUSE BLAST COVER CLOSURE APPEARS NORMAL.

E-12 Camera is located on the MLP deck and views the
400 FPS LH SRB southeast holddown post (HDP #5).
16mm

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: IGNITER SPARKS ARE BLOWN NORTHWARD. TYPICAL FACILITY DEBRIS IS DRAWN ACROSS THE DECK BY SSME PLUME ASPIRATION. T-0 OCCURS AT FRAME 4137. THERE IS NO EVIDENCE OF STUD HANG-UP, THE HDP SHOE IS STEADY DURING SEPARATION, AND NO DEBRIS FALLS FROM THE AFT SKIRT STUD HOLE. TYPICAL SRB THROAT PLUG MATERIAL IS EJECTED FROM THE SRB EXHAUST HOLE AT IGNITION.

E-13 Camera is located on the MLP deck and views the
400 FPS LH SRB southwest holddown post (HDP #6).
16mm

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: T-0 OCCURS AT FRAME 4171 AND A FLASH FROM THE ORDNANCE IS VISIBLE FROM THE BLAST CONTAINER VENT HOLE. A FOAM PARTICLE IS EJECTED FROM THE SRB EXHAUST HOLE AT IGNITION, BUT IS DRAWN BACK IN BY ASPIRATION. THE SRB AFT SKIRT GN2 PURGE LINE IS STILL VENTING AFTER LIFTOFF.

E-14 Camera is located on the MLP deck and views the
400 FPS LH SRB northwest holddown post (HDP #8).
16mm

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: T-0 OCCURS AT FRAME 4105. NUMEROUS PIECES OF SRB
THROAT PLUG MATERIAL ARE EJECTED FROM THE EXHAUST HOLE (FRAME
4115). SRB NOZZLE EXTENSION PASSES AS THE HDP DOGHOUSE BLAST
COVER CLOSES. SEVERAL LARGE PIECES OF SOUND SUPPRESSION WATER
TROUGH MATERIAL FALL FROM BEHIND THE SRB.

E-15 Camera is located on the MLP deck and views the RH
400 FPS SRB skirt, sound suppression water troughs, and RH
16mm lower Orbiter body flap.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: SSME IGNITION APPEARS NORMAL (FRAME 2340). ICE FALLS
FROM THE LO2 ET/ORB UMBILICAL AND LO2 T-0/TSM DURING SSME START
UP. T-0 OCCURS AT FRAME 4381. THE NEARLY EMPTY SECONDARY SOUND
SUPPRESSION WATER TROUGH IS BLOWN UPWARD BY THE SRB IGNITION OVER
PRESSURE WAVE, REACHES THE MAXIMUM EXTENSION OF THE TIE DOWN
CORDS, AND THEN FLAPS IN THE AIR FLOW. JUST AFTER THE AFT SKIRT
FEET PASS THE HDP BLAST COVERS (FRAME 4635), 40 PERCENT OF THE
BONDED HDP #3 SHIM SEPARATES FROM THE FOOT AND FALLS INTO THE SRB
EXHAUST HOLE. THE PIECE INCLUDES THE INBOARD SIDEWALL AND A
CUTOUT FOR THE STUD. THE HDP DOGHOUSE BLAST COVERS CLOSE AS THE
NOZZLE EXIT PLANE PASSES. A 5-INCH DEBRIS PARTICLE APPEARS NEAR
HDP #4 (FRAME 4777) AND MOVES DIAGONALLY UPWARD. PART OF THE
EXHAUST FLAME RISES ALONG HDP #4 AND MOMENTARILY IGNITES SOME
OF THE INSTAFOAM ON THE AFT SKIRT. NO DEBRIS FALLS FROM THE AFT
SKIRT STUD HOLES. TYPICAL FACILITY DEBRIS, WATER TROUGH MATERIAL,
AND INSTAFOAM EXIT THE SRB EXHAUST HOLE AFTER T-0.

E-16 Camera is located on the MLP deck and views the LH
400 FPS SRB skirt, sound suppression water troughs, and LH
16mm lower Orbiter body flap.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: SSME IGNITION APPEARS NOMINAL (FRAME 3421). ICE FROM THE LH2 ET/ORB UMBILICAL AND LH2 T-0/TSM FALLS DURING SSME START UP. RCS PAPER COVERS TEAR AND ARE PULLED INTO THE SSME PLUME. T-0 OCCURS AT FRAME 4392. OBJECT NEAR HDP #8 IS NOT RIGID AND BEHAVES LIKE WATER TROUGH MATERIAL. VIEW IS MOMENTARILY OBSCURED BY GEYSERING WATER FROM TROUGHS. BOTH HDP DOGHOUSE BLAST COVERS CLOSE AS THE NOZZLE EXIT PLANE PASSES BY. HDP #8 COVER LAGS HDP #7. ICE FALLING FROM THE GUCP ENTERS FOV ON THE RIGHT. DEBRIS APPEARING AFTER T-0 IS WATER TROUGH AND SRB THROAT PLUG MATERIAL.

E-17 Camera is located on the MLP deck and views the
400 FPS -Z side of the LO2 T-0 Umbilical and TSM.
16mm

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: SSME IGNITION (FRAME 1902) CAUSES BODY FLAP TO MOVE. RCS PAPER COVERS TEAR AND FALL FROM VEHICLE. ICE SHAKES LOOSE FROM LO2 T-0 UMBILICAL. A CLUSTER OF FIVE DINGS OCCURS ON THE BASE HEAT SHIELD TILES NEAR SSME #3 AND IS CAUSED BY IGNITION ACOUSTICS (FRAME 2306). ANOTHER DING NEAR THE EDGE OF THE HEAT SHIELD OCCURS AT FRAME 2690. SEVERAL OTHER MINOR DINGS ARE ALSO VISIBLE. FREE BURNING HYDROGEN IS BLOWN NORTHWARD. T-0 OCCURS AT FRAME 4242. DISCONNECTION OF THE T-0 UMBILICAL IS NOMINAL.

E-18 Camera is located on the MLP deck and views the
400 FPS -Z side of the LH2 T-0 umbilical and TSM.
16mm

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: FREE BURNING HYDROGEN IS BLOWN NORTHWARD. THERE IS BODY FLAP MOTION DURING SSME IGNITION. RCS PAPER COVERS TEAR AND FALL FROM THE VEHICLE. THE PURGE BARRIER ON THE LH2 TSM IS LOOSE/TORN. ICE PARTICLES FALL FROM THE LH2 ET/ORB AND T-0 UMBILICALS DURING SSME START UP. T-0 OCCURS AT FRAME 4407. LH2 T-0 UMBILICAL DISCONNECT IS NOMINAL.

E-19 Camera is located on the SE side of the MLP deck
400 FPS and views the SSME/OMS nozzles and Orbiter aft
16mm heat shield area.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: SSME HYDROGEN LEAD IS A CLOUD RATHER THAN A STREAM AS OBSERVED ON STS-34 (FRAME 1935). FREE BURNING HYDROGEN RISES TO BASE HEATSHIELD. SSME IGNITION APPEARS NOMINAL. RCS PAPER COVERS TEAR AND FALL INTO SSME PLUME. ICE PARTICLES SHAKE LOOSE FROM LO2 T-0 UMBILICAL. FROST SHAKES LOOSE FROM SSME #3 BELL NOZZLE. A SMALL PARTICLE, PROBABLY FROST, ORIGINATES UNDER THE OXYGEN DRAIN LINE NEAR HATBAND #7 (FRAME 3142). LO2 T-0 UMBILICAL DISCONNECT IS NOMINAL (FRAME 4364). THE LH2 TSM DOOR REBOUNDS DURING CLOSURE, BUT NOT AS MUCH AS LAST LAUNCH.

E-20 Camera is located on the SW side of the MLP deck
400 FPS and views the SSME/OMS nozzles and Orbiter aft
16mm heat shield area.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: SSME HYDROGEN LEAD IS A CLOUD RATHER THAN A STREAM. FREE BURNING HYDROGEN RISES TOWARD BASE HEAT SHIELD. SSME IGNITION APPEARS NOMINAL (FRAME 1911). RCS PAPER COVERS TEAR AND FALL FROM STINGER. ICE/FROST PARTICLES ARE SHAKEN LOOSE FROM SSME #1 NOZZLE-TO-HEAT SHIELD INTERFACE. LH2 T-0 UMBILICAL DISCONNECT IS NOMINAL (FRAME 4256). THE LO2 TSM DOOR REBOUNDS SLIGHTLY DURING CLOSURE.

E-21 Camera is located inside the LO2 TSM and views
200 FPS the disconnection of the T-0 umbilical.
16mm

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: T-0 OCCURS AT FRAME 2232. THE TSM DOOR REBOUND OF APPROXIMATELY 1/2 INCH IS LESS THAN STS-34. RESIDUAL LO2 VAPORS AND WATER CONDENSATE ARE VISIBLE IN THE AREA OF THE CARRIER PLATE. THE REDDISH COLOR (FRAME 2355) INSIDE THE LO2 T-0 MAIN FILL LINE QD IS EITHER REFLECTION FROM THE ORANGE INSULATION ON THE CARRIER PLATE OR REFLECTION OF THE SSME PLUME ON RESIDUAL GOX VAPORS.

E-22 Camera is located inside the LH2 TSM and views
200 FPS the disconnection of the T-0 umbilical.
16mm

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: THE TSM PURGE BARRIER BLOWS OUT OF THE DOOR OPENING AT
SSME IGNITION. T-0 OCCURS AT FRAME 2190. RESIDUAL LH2 VAPORS
EMANATE FROM THE ORBITER QD (FRAME 1232). THE TSM DOOR DID NOT
APPEAR TO BOUNCE DURING CLOSURE. WATER CONDENSATE AND SMALL
PIECES OF DEBRIS WERE VISIBLE BEHIND THE CARRIER PLATE INSIDE THE
TSM.

E-23 Camera is located on the MLP deck and views the
400 FPS RH OMS engine nozzle.
16mm

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: FREE BURNING HYDROGEN RISES AROUND RH RCS STINGER.
SSME IGNITION CAUSES RCS PAPER COVERS TO TEAR AND THE RH OMS
NOZZLE TO VIBRATE. THE SSME BETA BLANKETS APPEAR TO VIBRATE OR
'FLAP'. ICE FALLS FROM THE LO2 T-0 UMBILICAL. SSME ACOUSTICAL
VIBRATION CAUSES SMALL PIECES OF TILE SURFACE COATING MATERIAL TO
FALL OFF. THIS OCCURS ON THE BASE HEAT SHIELD BETWEEN THE OMS
NOZZLE AND SSME #3. T-0 OCCURS AT FRAME 4366. ICE FALLS FROM THE
LO2 T-0 UMBILICAL DURING DISCONNECT AND RETRACTION FROM THE
ORBITER. RESIDUAL GOX VAPORS ARE DRAWN INTO THE SSME PLUME BY
ASPIRATION.

E-24 Camera is located on the MLP deck and views the
400 FPS LH OMS engine nozzle.
16mm

Focus : SOFT
F. O. V.: OK
Exposure: OK

Comments: FREE BURNING HYDROGEN RISES TOWARD BASE HEAT SHIELD.
SSME STARTUP CAUSES RCS PAPER COVERS TO TEAR AND LH OMS NOZZLE TO
VIBRATE. A PARTICLE CLOSE TO THE LENS CROSSES THE FOV AT FRAME
2735. SSME IGNITION ACOUSTICS ALSO CAUSE A SMALL PIECE OF TILE
SURFACE COATING TO FALL FROM A BASE HEAT SHIELD TILE LOCATED

BETWEEN SSME #1 AND #2 (FRAME 2925). T-0 OCCURS AT FRAME 4426. ICE FALLS FROM BOTH THE ET/ORB UMBILICALS AND THE ORBITER LH2 T-0 UMBILICAL.

E-25 Camera is located on the east side of the MLP and
400 FPS views between Orbiter and ET/SRB during liftoff.
16mm

Focus : OK
F. O. V.: OK
Exposure: STILL UNDEREXPOSED

Comments: SSME IGNITION CAUSES BODY FLAP AND ELEVON MOTION. ICE FALLS FROM TSM CARRIER PLATE. T-0 OCCURS AT FRAME 3462. RESIDUAL LO2 VAPORS EMANATE FROM THE ORBITER QD. A 5-INCH PIECE OF DEBRIS FIRST APPEARS NEAR HDP #4 AND MOVES UPWARD AT A HIGH VELOCITY (FRAME 3972). THREE MORE 5-INCH PARTICLES APPEAR IN FRAME 3995 TO THE NORTH AND MOVING AWAY FROM THE VEHICLE. ONE PARTICLE FROM THE RH SRB EXHAUST HOLE IN THE AREA OF HDP #2 AND #4 MOVES UP AND TO THE NORTH CLOSE IN TO THE VEHICLE. A PARTICLE ENTERS FOV FROM THE EAST (FRAME 4034) AND PASSES TO THE NORTHEAST OF THE RH SRB. IT IS PROBABLY A BIRD SINCE IT IS NOT TRAVELING IN A STRAIGHT LINE. THE OBJECT IN THE AREA OF SSME #1 IS MOST LIKELY RCS PAPER COVER (FRAME 4368). TWO SIMILAR OBJECTS ARE OUTBOUND FROM SSME #1 AND ABOVE THE VERTICAL STABILIZER (FRAME 4402).

E-26 Camera is located on the west side of the MLP and
400 FPS views between Orbiter and ET/SRB during liftoff.
16mm

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: ICE FALLS FROM ET/ORB UMBILICALS. INBOARD AND OUTBOARD ELEVONS MOVE DURING SSME IGNITION. T-0 OCCURS AT FRAME 3528. THREE DEBRIS PARTICLES ARE VISIBLE NEAR THE LH SRB AND FALL AFT ALONG THE -Y SIDE (FRAME 3863). FOUR PIECES OF ICE FALLING FROM THE GUCP ENTER THE FOV FROM THE LEFT (FRAME 3974). AT THIS SAME TIME, A PARTICLE APPEARS ABOVE THE LH2 TSM, PASSES IN THE VICINITY OF THE VEHICLE, AND FALLS AFT. THE GH2 VENT ARM LATCHES PROPERLY AND DOES NOT REBOUND.

E-27 Camera is located on the MLP deck and views RH SRB
400 FPS northwest holddown post (HDP #3) blast cover.
16mm

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: T-0 OCCURS AT FRAME 4131. THE NEARLY-EMPTY SECONDARY
SOUND SUPPRESSION WATER TROUGH IS BLOWN UPWARD BY THE SRB
IGNITION OVER PRESSURE WAVE. THE WATER TROUGH REACHES THE MAXIMUM
EXTENSION OF THE TIE DOWN CORDS AND THEN FLAPS IN THE AIR FLOW.
NO ADVERSE EFFECTS ON THE VEHICLE WERE VISIBLE BY THE ABSENCE OF
WATER IN THIS TROUGH. AS THE VEHICLE SEPARATES FROM THE HOLDDOWN
POST SHOE, THE STUD IS STILL EXTENDED (10.07 INCHES). THE STUD
ROCKS BACK AND FORTH CONTACTING THE SIDES OF THE AFT SKIRT STUD
HOLE (BORE) AND LOOSENING THE SHIM BONDED TO THE SKIRT FOOT. A 40
PERCENT PIECE OF THE SHIM, WHICH INCLUDED THE INBOARD SIDEWALL
AND CUTOUT FOR THE STUD, FALLS FROM THE VEHICLE NEAR THE TOP OF
THE FRAME. THE STUD ROCKS BACK AND FORTH BEFORE DROPPING INTO THE
HOLDDOWN POST SAND BOX. A SMALL EXHAUST PLUME BACKFLOW MOMEN-
TARILY IGNITES A LOCALIZED AREA OF INSTAFOAM UNDER THE AFT SKIRT.
THE HDP DOGHOUSE BLAST COVER CLOSES AS THE SRB NOZZLE EXTENSION
PASSES.

E-28 Camera is located on the MLP deck and views LH SRB
400 FPS northeast holddown post (HDP #7) blast cover.
16mm

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: T-0 OCCURS AT FRAME 4224. SMALL PIECES OF SRB AFT
SKIRT INSTAFOAM ARE SHAKEN LOOSE BY IGNITION. SMALL CHUNKS OF SRB
THROAT PLUG MATERIAL ARE EJECTED FROM THE SRB EXHAUST HOLE. THE
HDP DOGHOUSE BLAST COVERS CLOSE AS THE SRB NOZZLE EXTENSION
PASSES.

E-30 Camera is located on the FSS 195 foot level and
400 FPS views LH SRB and sound suppression water troughs.
16mm

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: FREE BURNING HYDROGEN IS BLOWN NORTH UNDER THE BODY FLAP. T-0 OCCURS AT FRAME 4192. ICE FALLS FROM THE ET/ORB LH2 UMBILICAL. AFTER LIFTOFF, THE VEHICLE 'WALKS' NORTH MORE THAN 12 FEET. NUMEROUS, SMALL PIECES OF FACILITY DEBRIS ENTER FOV AFTER VEHICLE CLEARS THE TOWER.

E-31 Camera is located on the FSS 95 foot level and
100 FPS views the LH Orbiter wing, body flap, and
16mm ET/Orbiter LH2 umbilical area.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: SSME START-UP OCCURS AT FRAME 578. T-0 OCCURS AT FRAME 1139. SSME IGNITION CAUSES ORBITER LH INBOARD AND OUTBOARD ELEVON MOVEMENT. NUMEROUS PIECES OF ICE/FROST FALL FROM THE LH2 UMBILICAL AND RECIRCULATION LINE DURING SSME START-UP AND LIFT-OFF. A SMALL PIECE OF FROST GLANCES OFF THE ORBITER BODY FLAP, BUT NO TILE DAMAGE IS VISIBLE. A PIECE OF DEBRIS TRAVERSES THE FOV ABOVE THE MLP DECK.

E-33 Camera is located on the FSS 235 foot level and
200 FPS views the ET GH2 vent line and GUCP.
16mm

Focus : SOFT
F. O. V.: OK
Exposure: OK

Comments: T-0 OCCURS AT FRAME 1593. NUMEROUS PIECES OF ICE/FROST FALL FROM THE GUCP AT SSME START-UP (FRAME 703). NO TPS DAMAGE OR LOOSE FOAM IS OBSERVED AS THE GUCP DISCONNECTS FROM THE ET. RESIDUAL VAPORS EXIT THE ET UCP GH2 VENT. THE VEHICLE 'WALKS' NORTH APPROXIMATELY 13 FEET AS IT RISES FROM THE PAD.

E-34 Camera is located on FSS at 255 foot level and
300 FPS views upper Orbiter tile surfaces.
16mm

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: TWO PIECES OF ICE FALL FROM GUCP AT FRAME 1396. T-0 OCCURS AT FRAME 2192. THREE MORE PIECES OF ICE FALL FROM GH2 VENT LINE AS GUCP SEPARATES. VEHICLE 'WALKS' 13 FEET NORTH. FILM ITEM IS USEFUL FOR Z TRANSLATION OF VEHICLE BECAUSE OF SRB POSITION RELATIVE TO CAMERA VIEW. A SMALL PIECE OF DARK DEBRIS, PROBABLY FACILITY ROOFING MATERIAL, CROSSES FOV FROM RIGHT TO LEFT AFTER VEHICLE HAS CLEARED THE TOWER.

E-35 Camera is located on the FSS 255 foot level and
300 FPS views the mid-Orbiter/ET/SRB area.
16mm

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: FREE BURNING HYDROGEN IS BLOWN NORTHWARD. ICE FALLS FROM THE GUCP AND ET/ORB UMBILICALS. T-0 OCCURS AT FRAME 2293. GH2 VENT ARM RETRACTS AND SWINGS DOWN TO THE LATCHED POSITION IN A NORMAL MANNER. TWO PARTICLES APPEAR FROM BEHIND ET NEAR THE SRB EXHAUST HOLES AND MOVE OUTWARD AWAY FROM VEHICLE (FRAME 2682) - MAY BE PIECES OF SRB THROAT PLUG. AT FRAME 2937, FIVE PARTICLES ENTER FOV FROM RIGHT AND FALL NEAR VERTICAL STABILIZER. NO TILE ANOMALIES WERE VISIBLE. AN ORANGE, RIGID, PIECE OF DEBRIS CROSSES FOV AFTER VEHICLE CLEARS TOWER (FRAME 4947).

E-36 Camera is located on the FSS 255 foot level and
300 FPS views lower Orbiter, ET, SRB's, and water trough.
16mm

Focus : OK
F. O. V.: OK
Exposure: SOMEWHAT UNDEREXPOSED COMPARED TO OTHER ITEMS

Comments: FREE BURNING HYDROGEN IS VISIBLE UNDER VERTICAL STABILIZER AND BLOWN NORTH UNDER BODY FLAP. SSME IGNITION OCCURS IN FRAME 670. SEVERAL PIECES OF ICE FALL FROM ET/ORB UMBILICALS AND LH2 RECIRCULATION LINE BELLOWS. T-0 OCCURS AT FRAME 2505. LH2 T-0 UMBILICAL DISCONNECT AND RETRACTION IS NORMAL.

E-39 Camera is located on the FSS 185 foot level and
300 FPS views GH2 vent line latchback.
16mm

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: WATER DELUGE IS ALREADY FLOWING WHEN FILM STARTS. THE
GH2 VENT ARM LATCHES PROPERLY ON TOOTH #8 OF THE LATCHING
MECHANISM. VIEW OF THE GH2 VENT ARM RETRACTION LANYARD IS
OBSCURED BY WATER.

E-40 Camera is located on the FSS 275 foot level and
300 FPS views the ET ogive, SRB nosecone, and Orbiter
16mm tiled surfaces.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: VEHICLE TWANG APPEARS NORMAL. LIGHT FROST COVERS THE
-Y LOUVER. T-0 OCCURS AT FRAME 2705. ICE FALLS FROM ET/ORB UM-
BILICALS AS VEHICLE PASSES THROUGH FOV. CONDENSATE VAPORIZES ON
ET AFT DOME. WATER VAPOR STREAMS FROM RUDDER. SEVEN PARTICLES
FALL AFT OF VERTICAL STABILIZER AND PASS THROUGH SSME PLUME
(FRAME 4354). TWO OF THE PARTICLES APPEAR NEAR THE LEADING EDGE
OF THE TAIL (FRAME 4359). A PIECE OF FACILITY FOAM ROOFING
MATERIAL ENTERS FOV AFTER VEHICLE HAS CLEARED THE TOWER.

E-41 Camera is located on the FSS 255 foot level and
300 FPS views the GH2 vent line during rotation. Also
16mm shows clearance between structure and SRB aft
 skirt.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: T-0 OCCURS AT FRAME 2174. SLACK IN GH2 VENT ARM
RETRACT LANYARD APPEARS TO BE EXCESSIVE. GH2 VENT ARM LATCHES
PROPERLY AND DOES NOT REBOUND. LH SRB CLEARS VENT ARM HAUNCH BY
APPROXIMATELY 10 FEET DURING VEHICLE ASCENT. WATER FROM THE SRB
STIFFENER RINGS AND CONDENSATE ON THE ET AFT DOME VAPORIZE
SHORTLY AFTER LIFTOFF. SEVERAL PIECES OF FACILITY DEBRIS ENTER
FOV AFTER VEHICLE CLEARS TOWER.

E-42 Camera is located on the FSS 185 foot level and
300 FPS views the GH2 vent line drop, deceleration, and
16mm latchback.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: FIRST RETRACT LANYARD MOVEMENT (T-0) OCCURS AT FRAME 2085. GH2 VENT ARM LATCHES PROPERLY AND DOES NOT REBOUND. APPROXIMATELY 15 FEET OF SLACK REMAINS IN THE RETRACT LANYARD AT ARM LATCHBACK, WHICH ALLOWS THE CABLE TO WRAP AROUND THE GUCP SWIVEL HOUSING. THEREFORE, THE LANYARD WEIGHT OF 500 POUNDS WAS NOT IN THE LAUNCH LATCHED POSITION. SEVERAL PIECES OF FACILITY DEBRIS ENTER FOV AS VEHICLE RISES. THE VEHICLE HAS ADEQUATE CLEARANCE FROM THE HAUNCH DURING LIFT-OFF.

E-44 Camera is located on the FSS 155 foot level and
300 FPS views the LH OMS Pod leading edge tiles during
16mm ignition and liftoff.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: T-0 OCCURS AT FRAME 3115. SOME IGNITER SPARKS APPEAR NEAR THE OMS POD AND VERTICAL STABILIZER. VEHICLE 'TWANG' IS APPARENT DURING SSME START-UP. DISCONNECT AND RETRACTION OF THE ORBITER LH2 T-0 UMBILICAL APPEARS NOMINAL. RESIDUAL GH2 VAPORS EXIT THE ORBITER T-0 FLIGHT QD AS THE VEHICLE RISES.

E-48 Camera is located on the FSS 215 foot level (ET
300 FPS Intertank access arm structure) and views the GH2
16mm vent line during GUCP disconnection, rotation, and
latchback

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: T-0 OCCURS AT FRAME 2216. ICE FALLS FROM THE GUCP AT SSME IGNITION. NO TPS DAMAGE IS VISIBLE AROUND THE TANK UMBILICAL CARRIER PLATE. RESIDUAL VAPORS EXIT THE UCP GH2 VENT. THE GH2 VENT ARM RETRACT LANYARD HAS EXCESSIVE SLACK. THE VEHICLE 'WALKS' NORTH 13 FEET AFTER LIFTOFF.

E-50 Camera is located at camera site 1 at NE pad
60 FPS perimeter and views entire GH2 vent line and
16mm GUCP during rotation and latchback.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: FSS WATER DELUGE IS BLOWN NORTH BY THE WIND. VEHICLE
'TWANG' IS VISIBLE BY THE MOTION OF THE GH2 VENT ARM. GUCP DIS-
CONNECT AND GH2 VENT ARM RETRACTION IS NORMAL. THE ARM LATCHES
PROPERLY AND DOES NOT REBOUND. HOWEVER, THE GH2 VENT ARM RETRACT
LANYARD HAS EXCESSIVE SLACK.

E-52 Camera is located at camera site 2 on the east pad
96 FPS perimeter. Remote tracking of lower one-third of
35mm launch vehicle from ignition to 1200 feet.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: SEE COMMENTS FOR E-53. A PIECE OF FOAM DROPS FROM THE
AREA OF THE LH SRB ETA RING AND MAY HAVE ORIGINATED NEAR THE IEA.
THE PARTICLE TRAVERSING THE VEHICLE PLUME IN E-53 IS VISIBLE AT
188 FEET/01 FRAMES. A FLASH IN THE SSME PLUME OCCURS AT 124
FEET/00 FRAMES.

E-53 Camera is located at camera site 2 on the east pad
96 FPS perimeter. Remote tracking of middle one-third of
35mm launch vehicle from ignition to 1200 feet.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: FREE BURNING HYDROGEN IS BLOWN NORTH UNDER BODY FLAP.
SSME IGNITION CAUSES ICE TO FALL FROM THE ET/ORB UMBILICALS. GH2
VENT ARM RETRACTION AND LATCHBACK APPEAR NORMAL. FROST FALLS
ALONG THE FSS NORTH SIDE FROM THE FACILITY CRYOGENIC LINES. CON-
DENSATE ON THE ET AFT DOME VAPORIZES AFTER LIFTOFF. DURING EARLY
ASCENT, A BIRD FLIES UPWARD FROM THE BOTTOM OF THE FRAME MOVING
AWAY FROM THE VEHICLE. THE BIRD APPEARS TO BE CLOSE TO THE
CAMERA. WATER RUN-OFF AND CONDENSATE FALLS FROM THE VERTICAL STA-
BILIZER RUDDER/SPEED BRAKE SPLIT DURING EARLY ASCENT AND TOWER
CLEAR. ICE/FROST CONTINUES TO FALL FROM THE SSME HEAT SHIELD
INTERFACE AREA AND THE ET/ORB UMBILICALS AFTER TOWER CLEAR.
NUMEROUS PIECES OF RCS PAPER COVER FALL AFT OF THE VEHICLE INTO

THE SSME PLUME. AFTER THE ROLL MANEUVER, A BRIGHT PARTICLE TRAVERSES THE PLUME AS THE VEHICLE LEAVES THE FOV (216 FEET/15 FRAMES) .

E-54 Camera is located at camera site 2 on the east pad
96 FPS perimeter. Remote tracking of upper one-third of
35mm launch vehicle from ignition to 1200 feet.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: GH2 VENT ARM RETRACTION AND LATCHBACK APPEAR NORMAL. CONDENSATE ON THE ET AFT DOME VAPORIZES AFTER LIFTOFF. DURING EARLY ASCENT, A BIRD FLIES UPWARD FROM THE BOTTOM OF THE FRAME MOVING AWAY FROM THE VEHICLE. THE BIRD APPEARS TO BE CLOSE TO THE CAMERA. PAPER COVERS WERE INTACT ON THE FWD RCS THROUGH LOV. NO DEBRIS OR ICE PARTICLES WERE VISIBLE ON THE FORWARD PART OF THE VEHICLE.

E-57 Camera is located at camera site 6 on the NW pad
96 FPS perimeter. Remote tracking of lower one-third of
35mm launch vehicle from ignition to 1200 feet.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: SEE COMMENTS FOR E-58. ICE FALLS FROM THE ET/ORB UMBILICALS. WATER RUN-OFF AND CONDENSATE DRIPS FROM THE RUDDER/SPEED BRAKE SPLIT DURING EARLY ASCENT AND TOWER CLEAR.

E-58 Camera is located at camera site 6 on the NW pad
96 FPS perimeter. Remote tracking of center one-third of
35mm launch vehicle from ignition to 1200 feet.

Focus : OK
F. O. V.: OK
Exposure: OVEREXPOSED

Comments: FSS WATER DELUGE IS ALREADY FLOWING AT FILM START AND IS BLOWN NORTH BY THE WIND. BIRDS IN THE FOV ARE MOVING AWAY FROM THE VEHICLE. NO TPS DAMAGE IS VISIBLE AROUND THE ET GH2 UMBILICAL CARRIER PLATE, THOUGH RESIDUAL VAPORS ARE STILL VENTING FROM THE FLIGHT QD. CONDENSATE ON THE ET AFT DOME AND WATER FROM THE SRB STIFFENER RINGS VAPORIZE AFTER LIFTOFF.

E-59 Camera is located at camera site 6 on the NW pad
96 FPS perimeter. Remote tracking of upper one-third of
35mm launch vehicle from ignition to 1200 feet.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: FSS WATER DELUGE IS ALREADY FLOWING AT FILM START AND IS BLOWN NORTH BY THE WIND. BIRDS IN THE FOV ARE MOVING AWAY FROM THE VEHICLE. NO TPS DAMAGE IS VISIBLE AROUND THE ET GH2 UMBILICAL CARRIER PLATE, THOUGH RESIDUAL VAPORS ARE STILL VENTING FROM THE ET UCP GH2 VENT. PAPER COVERS ON THE FORWARD RCS ARE STILL INTACT THROUGH LOV.

E-60 Camera is located on north pad perimeter at camera
96 FPS site 1 and views the entire launch vehicle, FSS,
35mm and MLP zero level.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: SSME IGNITION APPEARS NORMAL. GH2 VENT ARM RETRACTION AND LATCHBACK APPEARS NORMAL. CONDENSATE ON THE ET AFT DOME AND WATER FROM THE SRB STIFFENER RINGS VAPORIZE AFTER LIFTOFF. ONE BIRD IS VISIBLE EAST OF THE VEHICLE AT SSME START UP THROUGH T-0 AND MOVING AWAY FROM THE VEHICLE. TWO BIRDS APPEAR AT 67 FEET/ 08 FRAMES. ONE IS EVEN WITH THE ORBITER TAIL AND THE OTHER OVER THE RSS ROOF SEEMS TO BE TRAVELING IN AN EASTERLY DIRECTION. THE BIRD OVER THE RSS APPEARS TO BE PULLED TOWARD THE VEHICLE PLUME BY ASPIRATION AT 83 FT/13 FRAMES. TWO PARTICLES EXIT THE SSME EX-HAUST CLOUD ABOUT 30 FEET ABOVE THE MLP DECK AND HEAD SOUTH AT 74 FT/10 FRAMES. WATER RUN-OFF AND CONDENSATE FALL FROM THE RUDDER/ SPEED BRAKE SPLIT DURING EARLY ASCENT AND TOWER CLEAR.

E-61 Camera is located at camera site 2 on the east pad
96 FPS perimeter and views the launch vehicle, FSS, and
35mm MLP.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: FREE BURNING HYDROGEN IS BLOWN NORTH UNDER THE BODY FLAP NEAR THE SRB AFT SKIRTS. WATER DELUGE ON THE FSS IS ALSO BLOWN NORTH. ICE FALLS FROM THE ET/ORB UMBILICALS DURING SSME IGNITION. GH2 VENT ARM RETRACTION AND LATCHBACK APPEARS NORMAL.

HELIUM PURGE IS STILL VENTING AND CONDENSATE DRIPS FROM THE GUCP DURING LATCHBACK. SEVERAL PARTICLES, PROBABLY FROST FROM THE FACILITY CRYOGENIC LINES, ARE NORTH OF THE FSS AT 43 FT/05 FRAME. TWO PARTICLES NORTH OF THE MLP (46 FT/00 FRAMES) APPEAR TO LEAD THE SRB PLUME AWAY FROM THE VEHICLE. A BIRD ABOVE THE RSS ROOF (52 FT/00 FRAMES) IS MOVING EASTWARD, BUT PULLED INTO THE PLUME BY ASPIRATION (58 FT/01 FRAMES).

E-62 Camera is located on the SE pad perimeter at
96 FPS camera site 3 and views entire vehicle, FSS, and
35mm MLP.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: WATER DELUGE FROM THE FSS IS BLOWN NORTH BY THE WIND. FREE BURNING HYDROGEN IS BLOWN NORTH UNDER THE BODY FLAP. LO2 T-0 UMBILICAL DISCONNECT AND RETRACTION APPEAR NORMAL. SEVERAL PARTICLES EXIT THE SRB EXHAUST HOLE AT 61 FT/13 FRAMES. A BIRD NORTH OF THE MLP IS MOVING AWAY (63 FT/10 FRAMES). ANOTHER BIRD FIRST APPEARS AT 74 FT/03 FRAMES FLYING EAST AND MOVING AWAY FROM THE VEHICLE. CONDENSATE ON THE ET AFT DOME AND WATER FROM THE SRB STIFFENER RINGS VAPORIZE SHORTLY AFTER LIFTOFF. PAPER COVERS ON THE FORWARD RCS ARE INTACT UNTIL VEHICLE LEAVES FOV.

E-63 Camera is located on SW pad perimeter at camera
96 FPS site 4 and views entire launch vehicle, FSS, and
35mm MLP.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: FREE HYDROGEN BURNS UNDER THE MLP IN THE EXHAUST TRENCH DURING SSME IGNITION. ICE FALLS FROM THE ET/ORB UMBILICAL AREA. WATER FROM THE SRB STIFFENER RINGS VAPORIZE SHORTLY AFTER LIFTOFF. A PARTICLE, OR BIRD, FIRST APPEARS EVEN WITH THE RH SRB AFT SKIRT MOVING FROM LEFT TO RIGHT AT 67 FT/02 FRAMES. RCS PAPER COVERS WERE STILL INTACT THROUGH LOV.

E-64 Camera is located on NW pad perimeter at camera
96 FPS site 6 and views entire launch vehicle, FSS, and
35mm MLP.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: WATER DELUGE FROM THE FSS IS BLOWN NORTH BY THE WIND.
CONDENSATE ON THE ET AFT DOME AND WATER FROM THE SRB STIFFENER
RINGS VAPORIZE SHORTLY AFTER LIFTOFF. RESIDUAL VAPORS EXIT THE ET
UCP GH2 VENT AREA. WATER RUN-OFF AND CONDENSATE DRIP FROM THE
RUDDER/SPEED BRAKE DRAIN HOLE DURING EARLY ASCENT.

E-76 Camera is located on SE pad perimeter at camera
96 FPS site 3 and views SSME engines #1 and #3 and the RH
35mm OMS engine nozzle.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: FREE BURNING HYDROGEN RISES TO BASE HEAT SHIELD NEAR
SSME #1 AND #3. SSME IGNITION OCCURS AT 11 FT/02 FRAMES. SSME IG-
NITION CAUSES ICE TO FALL FROM THE ET/ORB LO2 UMBILICAL AND THE
LO2 T-0 UMBILICAL. THE PURGE BARRIER IN THE LH2 TSM DOOR FLAPS IN
THE AIR FLOW. VEHICLE 'TWANG' IS VISIBLE BY VERTICAL STABILIZER
MOTION. T-0 OCCURS AT 45 FT/09 FRAMES. LO2 T-0 UMBILICAL DISCON-
NECT AND LH2 TSM DOOR CLOSURE APPEAR TO BE NOMINAL. RESIDUAL GOX
VAPORS FROM THE T-0 UMBILICAL ARE DRAWN INTO THE SSME PLUME BY
ASPIRATION. ICE CONTINUES TO FALL FROM THE ET/ORB LO2 UMBILICAL
(VISIBLE BEHIND THE BODY FLAP). WATER FROM THE SRB STIFFENER
RINGS VAPORIZES AFTER LIFTOFF. THERE WERE NO OMS POD ANOMALIES.

E-77 Camera is located on SW pad perimeter at camera
96 FPS site 4 and views SSME engines #1 and #2 and the LH
35mm OMS engine nozzle.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: FREE BURNING HYDROGEN RISES TO BASE HEAT SHIELD NEAR
SSME #1 AND #2. SSME IGNITION CAUSES ICE TO FALL FROM THE LH2 T-0
UMBILICAL AND THE ET/ORB LH2 UMBILICAL. THE LH OMS NOZZLE
VIBRATES SLIGHTLY DURING SSME STARTUP. PAPER COVERS FROM THE LH
RCS STINGER TEAR AND FALL INTO SSME PLUME. DISCONNECT AND RETRAC-
TION OF THE LH2 T-0 UMBILICAL IS NORMAL. ICE CONTINUES TO FALL

FROM THE LH2 ET/ORB UMBILICAL (BEHIND THE BODY FLAP). WATER FROM THE SRB STIFFENER RINGS VAPORIZES SHORTLY AFTER LIFTOFF. THERE WERE NO LH OMS POD ANOMALIES.

E-201 UCS-9 IFLOT tracking of launch vehicle from
30 FPS ignition and early flight through LOV.
70mm

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: CONDENSATE ON ET AFT DOME AND WATER FROM SRB STIFFENER RINGS VAPORIZE SHORTLY AFTER LAUNCH. SOME RCS PAPER COVERS ARE VISIBLE FALLING FROM VEHICLE DURING ASCENT. FLASHES OCCUR IN THE SSME PLUME THROUGHOUT FLIGHT. STARTING AT FRAME 1906, ONE PARTICLE FALLS ALONG THE LEFT OF THE PLUME, AND TWO PARTICLES ARE DOWNSTREAM IN THE PLUME. AT FRAME 1956, A FOURTH PARTICLE IS VISIBLE. THE AFT END OF THE ORBITER IS OBSCURED BY THE PLUME - ONLY THE RIGHT WING AND VERTICAL STABILIZER ARE VISIBLE. AT GMT 24:30.60, A BRIGHT REDDISH, OR PLUME-COLORED, OBJECT FIRST APPEARS OUT OF THE SRB PLUME NEAR THE SRB AFT SKIRT AREA (AND SEEMS TO BE OUTBOARD OF THE ORB/ET). THE OBJECT IS VISIBLE FOR 11 FRAMES AND THEN LOST FROM VIEW AGAINST THE BRIGHT PART OF THE PLUME. THE OBJECT AND VEHICLE ARE TOO DISTANT FOR DETAIL.

E-202 UCS-15 IFLOT tracking of launch vehicle from
30 FPS ignition and early flight through LOV.
70mm

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: CONDENSATE ON THE ET LH2 AFT DOME VAPORIZES SHORTLY AFTER LAUNCH. WATER RUN-OFF AND CONDENSATE DRIP FROM THE RUDDER/SPEED BRAKE SPLIT. SOME DEBRIS (POSSIBLY RCS PAPER COVERS) FALLS AFT OF THE VEHICLE DURING EARLY ASCENT.

E-203 UCS-6 IFLOT tracking of launch vehicle from
30 FPS ignition and early flight through LOV.
70mm

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: CONDENSATE ON THE ET LH2 AFT DOME VAPORIZES SHORTLY AFTER LIFTOFF. WATER RUN-OFF AND CONDENSATE DRIP FROM THE RUDDER/SPEED BRAKE SPLIT THROUGH TOWER CLEAR. TWO PARTICLES ARE VISIBLE; ONE ABOVE AND ONE BELOW THE PLUME AT FRAME 2263. NO ET AFT DOME ANOMALIES.

E-204 PAFB IGOR tracking of launch vehicle from
48 FPS acquisition to SRB separation. Tracks ET/ORB
35mm after SRB separation to LOV.

Focus : OK
F. O. V.: INCONSISTENT
Exposure: UNDEREXPOSED

Comments: AN AERODYNAMIC VORTEX FORMS AFT OF THE ORBITER BODY FLAP. FLASHES OCCUR IN THE SSME PLUME DURING ASCENT. PLUME RECIRCULATION NEAR THE ET AFT DOME BEGINS AT 275 FT/00 FRAMES AND ENDS AT 334 FT/00 FRAMES. CLINKERS ARE VISIBLE IN SRB PLUMES PRIOR TO AND AFTER SRB SEPARATION. AFT BSM'S FIRE AT 370 FT/08 FRAMES FOLLOWED ONE FRAME LATER BY THE FORWARD BSM'S.

E-205 Shiloh IFLOT tracking of launch vehicle from
48 FPS acquisition to SRB separation. Tracks ET/ORB
35mm after SRB separation to LOV.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: WATER FROM SRB STIFFENER RINGS VAPORIZES SHORTLY AFTER LIFTOFF. LOCAL SUPERSONIC FLOW CONDENSATION FORMS ON THE VEHICLE AT 22 FT/00 FRAMES. THE VEHICLE IS OBSCURED BY THE PLUME DURING PART OF THE TRACKING. SRB SEPARATION OCCURS AT 270 FT/00 FRAMES. CLINKERS APPEAR IN THE SRB PLUMES PRIOR TO AND AFTER SEPARATION.

E-206 Melbourne Beach ROTI tracking of launch vehicle
48 FPS from acquisition to SRB separation. Tracks ET/ORB
35mm after SRB separation to LOV.

Focus : SOFT
F. O. V.: OK
Exposure: UNDEREXPOSED

Comments: PLUME RECIRCULATION NEAR THE ET AFT DOME BEGINS AT 229 FT/00 FRAMES AND ENDS AT 294 FT/00 FRAMES. SRB SEPARATION OCCURS AT 326 FT/07 FRAMES WITH FIRING OF THE AFT BSM'S FOLLOWED ONE FRAME LATER BY FIRING OF THE FORWARD BSM'S. NUMEROUS (MORE THAN 100) CLINKERS ARE VISIBLE IN THE SRB PLUMES PRIOR TO, DURING, AND AFTER SEPARATION.

E-207 UCS-10 MIGOR tracking of launch vehicle from
96 FPS acquisition to SRB separation. Tracks ET/ORB
35mm after SRB separation to LOV.

Focus : OK
F. O. V.: INVERTED IMAGE
Exposure: OK

Comments: INSTAFOAM OUTGASSES FROM SRB AFT SKIRTS. SLIGHT CHARRING OCCURS ON THE ET AFT DOME APEX BETWEEN THE MANHOLE COVERS. FIVE PIECES OF RCS PAPER COVERS FALL FROM THE VEHICLE BETWEEN 25 FT/12 FRAMES TO 31 FT/15 FRAMES. BODY FLAP MOTION IS VISIBLE FROM ACQUISITION THROUGH LOV. THE MOVEMENT IS SIMILAR IN MAGNITUDE AND FREQUENCY TO THAT PREVIOUSLY OBSERVED ON OTHER ORBITERS. THE ELEVONS MOVE THROUGH SCHEDULED LOAD RELIEF DEFLECTIONS. PARTICLES FALL FROM THE SRB PLUMES AT 250 FT/04 FRAMES, 264 FT/03 FRAMES, 275 FT/08 FR, 338 FT/11 FR, AND 672 FT/14 FR. BSM FIRING OCCURS AT 684 FT/14 FRAMES. NUMEROUS (MORE THAN 100) CLINKERS APPEAR OUT OF THE SRB PLUMES AT SRB TAIL OFF AND SEPARATION.

E-208 Cocoa Beach DOAMS tracking of launch vehicle
48 FPS from acquisition to SRB separation. Tracks ET/ORB
35mm after SRB separation to LOV.

Focus : SOFT DUE TO CAMERA SHAKE
F. O. V.: IMAGE IS INVERTED
Exposure: OK

Comments: PLUME RECIRCULATION NEAR THE ET AFT DOME OCCURS AT 142 FT/14 FRAMES AND IS A TYPICAL OCCURRENCE. CLINKERS APPEAR OUT OF THE SRB EXHAUST PLUME PRIOR TO AND AFTER SRB SEPARATION, WHICH OCCURS AT 235 FT/02 FRAMES.

E-209 UCS-13 IFLOT intermediate tracking of
30 FPS launch vehicle from acquisition to LOV.
70mm

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: AT GMT 24:30.63, A LONG, THIN OBJECT IS VISIBLE ALONG THE LEFT EDGE OF THE SRB PLUME (FRAME 9934). THE OBJECT IS VISIBLE FOR 10 FRAMES, DISAPPEARS FOR 3 FRAMES, AND REAPPEARS FOR 4 MORE FRAMES. THE VIEW IS TOO DISTANT FOR DETAIL, BUT THE OBJECT MAY BE ELONGATED DUE TO THE SLOW FRAME RATE AND CAMERA SHAKE. CLINKERS APPEAR OUT OF THE SRB PLUMES PRIOR TO SRB SEPARATION.

E-210 UCS-26 IFLOT intermediate tracking of
30 FPS launch vehicle from acquisition to LOV.
70mm

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: VIEW IS TOO DISTANT FOR FINE DETAIL. SOME CLINKERS FALL OUT OF THE SRB PLUMES JUST PRIOR TO SRB SEP.

E-211 UCS-13 IFLOT intermediate tracking of forward
96 FPS portion of ORB and ET from acquisition to LOV.
35mm

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: THE CAMERA IS WEST OF THE PAD AND THE VIEW IS LOOKING UP AT THE ET AFT DOME AND SRB EXHAUST PLUMES DURING ASCENT. FRAME RATE OF THE CAMERA IS SLIGHTLY SLOW AT 91 FRAMES PER SECOND. A BIRD CROSSES THE FOV, BUT IS NOT NEAR THE VEHICLE. THE ROLL MANEUVER APPEARS NORMAL. CONDENSATE ON THE ET AFT DOME AND WATER FROM THE SRB STIFFENER RINGS VAPORIZE SHORTLY AFTER LIFTOFF. LOCAL SUPERSONIC FLOW CONDENSATION FORMS ON THE VEHICLE IN THE MAX Q REGION. SOME SLIGHT CHARRING OCCURS ON THE ET AFT DOME. AT GMT 24:30.64, A BRIGHT, OR PLUME-COLORED, OBJECT APPEARS OUT OF THE SRB PLUME ABOUT HALF WAY DOWN THE BRIGHT SECTION OF PLUME (389 FT/14 FRAMES). THE OBJECT FALLS ALONG THE EDGE AND IS STILL BRIGHT PAST THE DARK PART OF THE PLUME. THE OBJECT IS VISIBLE FOR 35 FRAMES AND IS JOINED BY A SECOND BRIGHT OBJECT OUT OF THE

PLUME AFTER 17 FRAMES. OTHER PARTICLES ARE VISIBLE AT 400 FT/12 FRAMES AND 408 FT/14 FRAMES THROUGH 410 FT/ 10 FRAMES. SRB SEPARATION IS DISTANT IN THIS VIEW.

E-212 UCS-23 MIGOR tracking of launch vehicle
96 FPS from acquisition to LOV.
35mm

Focus : OK
F. O. V.: IMAGE INVERTED
Exposure: OK

Comments: BODY FLAP MOTION OCCURS. MAGNITUDE AND FREQUENCY APPEAR SIMILAR TO THAT OBSERVED ON PREVIOUS VEHICLE. A FLASH OCCURS IN THE SSME PLUME AT 205 FT/00 FRAMES. PLUME RECIRCULATION NEAR THE ET AFT DOME BEGINS AT 384 FT/00 FRAMES AND IS A NORMAL OCCURRENCE. SRB'S SEPARATE FROM THE ET AT 511 FT/01 FRAMES. CLINKERS APPEAR OUT OF THE SRB PLUMES PRIOR TO, DURING, AND AFTER SRB SEPARATION.

E-213 UCS-7 MOTS tracking of forward portion of ORB and
96 FPS ET from acquisition to LOV.
35mm

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: CONDENSATE ON THE ET AFT DOME AND WATER FROM THE SRB STIFFENER RINGS VAPORIZE SHORTLY AFTER LIFTOFF. RCS PAPER COVERS FALL FROM THE VEHICLE DURING EARLY ASCENT AND THROUGH THE ROLL MANEUVER. AN AERODYNAMIC VORTEX FORMS AFT OF THE LH WING TIP AFTER THE ROLL MANEUVER. FORWARD RCS PAPER COVERS APPEAR OVER THE LH WING MOVING AFT AT 90 FT/00 FRAMES. THE ET HYDROGEN FIRE DETECTION PAPER COMES INTO VIEW UNDER THE ORBITER WING. BODY FLAP MOTION IS VISIBLE. THE MAGNITUDE AND FREQUENCY OF THE MOVEMENT IS SIMILAR TO THAT OBSERVED ON PREVIOUS ORBITERS. PARTICLES APPEAR OUT OF THE SRB PLUMES AT 121 FT/08 FRAMES AND 124 FT/11 FRAMES. AT 126 FT/07 FRAMES, SMALL PARTICLES FIRST APPEAR NEAR THE RH SRB IEA AREA.

E-217 Beach Road IFLOT close-in tracking of launch
30 FPS vehicle during ignition, liftoff, and early
70mm portion of flight through LOV.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: CONDENSATE ON THE ET AFT DOME AND WATER FROM THE SRB STIFFENER RINGS VAPORIZE SHORTLY AFTER LIFTOFF. AN AERODYNAMIC VORTEX FORMS AFT OF THE LH WING TIP JUST AFTER THE ROLL MANEUVER. LOCAL SUPERSONIC FLOW CONDENSATION OCCURS AT FRAME 1404.

E-218 UCS-26 IFLOT intermediate tracking of
96 FPS launch vehicle from acquisition through LOV.
35mm

Focus : SOFT
F. O. V.: OK
Exposure: OK

Comments: CONDENSATE ON ET AFT DOME AND WATER FROM SRB STIFFENER RINGS VAPORIZE SHORTLY AFTER LIFTOFF. WATER RUN-OFF AND CONDENSATE STREAM AFT FROM RUDDER/SPEED BRAKE SPLIT. FLASHES OCCUR IN THE SSME PLUME DURING ASCENT. LOCAL SUPERSONIC FLOW CONDENSATION FORMS ON THE VEHICLE AT 207 FT/10 FRAMES. THE VIEW FROM THE SOUTH IS ALMOST PERPENDICULAR TO THE VEHICLE AT FIRST ACQUISITION, THEN MOVES AFT TO AN ANGLE ABOUT 30 DEGREES. THIS VIEW PROVIDES A RELATIVELY CLEAR SPACE BETWEEN THE ORBITER, SSME'S, ET, AND SRB'S (EXCEPT FOR THE AFT SKIRTS). THE FOCUS IS SOMEWHAT SOFT, BUT GOOD DETAIL IS STILL DISCERNIBLE. NO OBJECTS WERE OBSERVED CROSSING THE 'SPACE' FROM THE VEHICLE TO THE PLUME DURING THE TIME FROM GMT 24:18 TO 24:46. CLINKERS APPEAR OUT OF SRB PLUMES PRIOR TO AND AFTER SRB SEPARATION.

E-219 UCS-3 IFLOT close-in tracking of launch
30 FPS vehicle during ignition, liftoff, and early
70mm portion of flight through LOV.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: CONDENSATE ON THE ET AFT DOME AND WATER FROM THE SRB STIFFENER RINGS VAPORIZE SHORTLY AFTER LIFTOFF. NO VEHICLE ANOMALIES DURING ASCENT OR AT SRB SEPARATION.

E-220 UCS-15 IFLOT close-in tracking of forward
96 FPS portion of ORB and ET during ignition, liftoff,
35mm and early portion of flight through LOV.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: CONDENSATE OF ET AFT DOME AND WATER FROM SRB STIFFENER RINGS VAPORIZE SHORTLY AFTER LIFTOFF. AN AERODYNAMIC VORTEX FORMS AFT OF THE LH WING TIP AFTER THE ROLL MANEUVER. RCS PAPER COVERS AND ET HYDROGEN FIRE DETECTION SYSTEM PAPER FALL FROM THE VEHICLE THROUGH EARLY ASCENT. FLASHES OCCUR IN THE SSME PLUME. MOVEMENT OF THE ORBITER BODY FLAP APPEARS TO BE SIMILAR IN MAGNITUDE AND FREQUENCY COMPARED TO PREVIOUS VEHICLES. LOCAL SUPERSONIC FLOW CONDENSATION FORMS ON THE FORWARD PART OF THE VEHICLE AT 220 FT/00 FRAMES.

E-221 UCS-3 IFLOT close-in tracking of forward
96 FPS portion of ORB and ET during ignition, liftoff, and early
35mm portion of flight through LOV.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: CONDENSATE ON ET AFT DOME AND WATER FROM SRB STIFFENER RINGS VAPORIZE SHORTLY AFTER LIFTOFF. AN AERODYNAMIC VORTEX FORMS AFT OF THE LH WING TIP AFTER THE ROLL MANEUVER. SLIGHT CHARRING OCCURS ON THE ET AFT DOME. GAS DYNAMIC EFFECTS ARE VISIBLE IN THE SSME PLUME DURING ASCENT. ET HYDROGEN FIRE DETECTION SYSTEM PAPER APPEAR UNDER THE LH WING AT 155 FT/00 FRAMES. A RED PIECE OF RCS PAPER COVER COMES FROM THE RIGHT SIDE AND FALLS AFT OF THE SSME'S AT 173 FT/00 FR. A PARTICLE IS VISIBLE AFT OF THE LH WING AT 175 FT/06 FR. A RED FLASH OCCURS IN THE SSME PLUME AT 250 FT/09 FR. A VAPOR TRAIL FORMS AFT OF THE RH WING ELEVON (261 FT/05 FR), BEGINS THICK, THEN TAPERS OFF (262 FT/03 FR). SRB SEPARATION OCCURS AT 730 FT/11 FRAMES.

E-222 Beach Road IFLOT close-in tracking of forward
96 FPS portion of ORB and ET during ignition, liftoff,
35mm and early portion of flight through LOV.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: CONDENSATE ON ET AFT DOME AND WATER FROM SRB STIFFENER RINGS VAPORIZE SHORTLY AFTER LIFTOFF. RCS PAPER COVERS AND ET HYDROGEN FIRE DETECTION SYSTEM PAPER FALLS FROM THE VEHICLE THRU EARLY ASCENT. AN AERODYNAMIC VORTEX FORMS AFT OF THE LH WING TIP AFTER THE ROLL MANEUVER. MOVEMENT OF THE BODY FLAP IS SIMILAR IN MAGNITUDE AND FREQUENCY PREVIOUSLY OBSERVED ON OTHER ORBITERS. SLIGHT CHARRING OCCURS ON THE ET AFT DOME. FLASHES ARE VISIBLE IN THE SSME PLUME AT 310 FT/12 FRAMES AND 325 FT/01 FR. LOCAL SUPER-SONIC FLOW CONDENSATION FORMS ON THE FORWARD PART OF THE VEHICLE. SRB SEPARATION OCCURS AT 837 FT/00 FRAMES.

E-223 UCS-9 IFLOT intermediate tracking of forward
96 FPS portion of ORB and ET during ignition, liftoff,
35mm and early portion of flight through LOV.

Focus : OK
F. O. V.: OK, BUT TRACKING IS ERRATIC
Exposure: OK

Comments: CONDENSATE ON ET AFT DOME AND WATER FROM SRB STIFFENER RINGS VAPORIZE SHORTLY AFTER LIFTOFF. RCS PAPER COVERS AND ET HYDROGEN FIRE DETECTION SYSTEM PAPER FALL FROM THE VEHICLE THRU EARLY ASCENT. AT GMT 24:30.64, A BRIGHT, RING-SHAPED OBJECT WITH A DARK INTERIOR, OR A VERY BRIGHT VERY BLURRED DOT, FIRST APPEARS EVEN WITH THE RH WING (AS SEEN FROM THE GROUND) FALLING OUT OF THE SRB PLUME NEAR THE AFT SKIRT AREA. THE OBJECT IS VISIBLE FOR 32 FRAMES ALONG SIDE THE PLUME (355 FT/05 FRAMES - 357 FT/07 FR), DISAPPEARS AGAINST THE BRIGHT PART OF THE PLUME FOR 6 FRAMES, AND REAPPEARS AGAINST THE DARK PART OF THE PLUME (359 FT/05 FR - 361 FT/07 FR). AT THIS TIME, THE PLUME OBSCURES MOST OF THE VEHICLE WITH ONLY THE RH WING TIP, SSME #1, AND THE VERTICAL STABILIZER VISIBLE. A SECOND, SIMILAR OBJECT APPEARS AT 365 FT/10 FRAMES TO 366 FT/04 FRAMES FOLLOWED BY A THIRD, VERY FAINT OBJECT AT 366 FT/11 FRAMES TO 368 FT/00 FRAMES.

E-233 Castglance airborne tracking
35mm

Comments: FILM WAS NOT RUN DUE TO LACK OF LIGHT SOURCE.

E-234 Castglance airborne tracking
16mm

Comments: FILM WAS NOT RUN DUE TO LACK OF LIGHT SOURCE.

E-301 RH SRB parachute deployment
200 FPS
16mm

Comments: FILM WAS BLANK DUE TO LACK OF LIGHT SOURCE.

E-302 LH SRB parachute deployment
200 FPS
16mm

Comments: FILM WAS BLANK DUE TO LACK OF LIGHT SOURCE.

LAUNCH ITEMS: VIDEO

OTV 101 Views the Orbiter LH2 T-0 umbilical from the FSS
B/W M-II 255 foot level.

Comments: GASEOUS OXYGEN FROM THE SSME'S IS BLOWN NORTH BY THE WIND. WATER DELUGE IN THE SSME EXHAUST HOLE IS ACTIVATED AT T-15 SECONDS. THE LIGHT FOR THE TSM INTERIOR CAMERA SHINES ON THE AFT FUSELAGE OF THE ORBITER AT T-12 SECONDS. VEHICLE 'TWANG' IS VISIBLE BY THE MOTION OF THE T-0 CARRIER PLATE. LH2 T-0 UMBILICAL DISCONNECT AND RETRACTION APPEAR NOMINAL. RESIDUAL LH2 VAPORS EXIT THE ET UCP GH2 VENT AFTER LIFTOFF.

OTV 103 Views GUCP and GH2 vent line.
B/W M-II

Comments: SSME IGNITION CAUSES ICE TO FALL FROM THE GUCP. VEHICLE 'TWANG' IS VISIBLE BY THE MOTION OF THE GH2 VENT ARM. GUCP DISCONNECT AND VENT ARM RETRACTION ARE NORMAL. ONE FROST AREA, BUT NO DAMAGE, APPEAR ON THE TPS AREA NEAR THE FLIGHT UMBILICAL CARRIER PLATE.

OTV-109 Views ET/Orbiter LH2 umbilical area from the 95
B/W M-II foot level of the FSS.

Comments: CAMERA VIEWED LH SRB AFT BOOSTER AND SRB EXHAUST HOLE AREA. GASEOUS OXYGEN FROM THE SSME'S AS WELL AS SMOKE AND SPARKS FROM THE IGNITERS ARE BLOWN NORTH BY THE WIND. FREE BURNING HYDROGEN IS ALSO BLOWN NORTH UNDER THE BODY FLAP AND GOES AS FAR AS THE SRB AFT BOOSTERS. ALTHOUGH SOME OF THE HYDROGEN AND ROFI

SMOKE IS DRAWN BACK INTO THE SSME PLUME BY ASPIRATION, SOME OF THE BURNING HYDROGEN RISES AND DISSIPATES. SRB IGNITION CAUSES WATER IN THE SOUND SUPPRESSION WATER TROUGHS TO GEYSER.

OTV 141 Views and tracks vehicle from camera site 2.
B/W

Comments: FSS WATER DELUGE IS ACTIVATED AT T-15 SECONDS AND IS BLOWN NORTH BY THE WIND. FREE BURNING HYDROGEN IS BLOWN NORTH. SSME IGNITION APPEARS NORMAL. VEHICLE TRACKING IS LOST SOON AFTER ROLL MANEUVER

OTV 143 Views east side of launch vehicle and pad from
B/W camera site 2.

Comments: FSS WATER DELUGE IS ACTIVATED AT T-15 SECONDS AND BLOWN NORTH BY THE WIND. VEHICLE 'TWANG' IS VISIBLE AGAINST THE FSS IN THE BACKGROUND. THE VIEW IS OVEREXPOSED AFTER T-0.

OTV 148 Launch and tracking view from camera site 6.
B/W

Comments: FSS WATER DELUGE IS BLOWN NORTH BY THE WIND. NO VEHICLE ANOMALIES WERE VISIBLE. CONDENSATE ON ET AFT DOME VAPORIZES SHORTLY AFTER LIFTOFF. THE SRB PLUME OBSCURES THE VEHICLE AFTER THE ROLL MANEUVER.

OTV 149 Views Orbiter LO2 T-0 umbilical from MLP deck.
B/W M-II

Comments: SSME IGNITION ACOUSTICS CAUSE RCS PAPER COVERS TO TEAR AND ICE TO FALL FROM THE LO2 T-0 UMBILICAL. VEHICLE 'TWANG' IS VISIBLE BY THE MOTION OF THE T-0 CARRIER PLATE. UMBILICAL DISCONNECT AND RETRACTION IS NORMAL. RESIDUAL GOX VAPORS ARE DRAWN INTO THE SSME PLUME BY ASPIRATION.

OTV 150 Views Orbiter LH2 T-0 umbilical from SW MLP deck.
B/W M-II

Comments: VEHICLE 'TWANG' IS VISIBLE BY THE MOTION OF THE T-0 CARRIER PLATE. UMBILICAL DISCONNECT AND RETRACTION ARE NORMAL. RESIDUAL LH2 VAPORS ARE DRAWN INTO THE SSME PLUME BY ASPIRATION.

OTV 151 Views main engine cluster.
B/W M-II

Comments: START OF SSME IGNITION CAUSES FREE BURNING HYDROGEN TO RISE TO BASE HEAT SHIELD. ENGINE IGNITION ACOUSTICS SHAKES ICE LOOSE FROM THE LO2 T-0 UMBILICAL AND TEARS RCS PAPER COVERS. SSME GIMBAL FOR FLIGHT IS NORMAL.

OTV 154 Views ET/Orbiter LO2 umbilical and Orbiter RH wing
B/W M-II

Comments: VENTING OF PURGE GAS FROM THE ET/ORB LH2 UMBILICAL IS NORMAL. SSME IGNITION CAUSES A HEAVY SHOWER OF ICE/FROST TO FALL FROM THE ET/ORB UMBILICALS. ALTHOUGH THE ICE FALLS PAST THE BODY FLAP, NO TILE DAMAGE IS VISIBLE.

OTV 155 Views RH SRB and underside of Orbiter RH wing.
B/W M-II

Comments: FREE BURNING HYDROGEN IS BLOWN NORTH UNDER THE BODY FLAP. SSME IGNITION SHAKES ICE FROM THE ET/ORB LO2 UMBILICAL LOOSE, BUT NO TILE DAMAGE IS VISIBLE. THE TV IMAGE DROPS OUT AFTER SRB IGNITION.

OTV 156 Views LH SRB and underside of Orbiter LH wing.
B/W M-II

Comments: FREE BURNING HYDROGEN IS BLOWN NORTH UNDER THE BODY FLAP. SSME IGNITION SHAKES ICE LOOSE FROM THE ET/ORB LH2 UMBILICAL, BUT NO TILE DAMAGE IS VISIBLE. SRB IGNITION CAUSES WATER IN THE SOUND SUPPRESSION WATER TROUGHS TO GEYSER.

OTV 160 Views ET nosecone and NE louver from water tower.
Color M-II

Comments: FSS WATER DELUGE IS ACTIVATED AT T-15 SECONDS AND IS BLOWN NORTH BY THE WIND. VEHICLE 'TWANG' APPEARS NORMAL. THE GH2 VENT ARM DISCONNECTS, LATCHES, AND DOES NOT REBOUND. NO VEHICLE ANOMALIES.

OTV 161 Views ET nosecone and SW louver from the FSS.
Color M-II

Comments: LIGHT FROST COATS THE LOUVER. THERE WAS NO MISSING TPS OR TOPCOAT FROM THE NOSECONE/FOOTPRINT AREA. NO ANOMALIES WERE VISIBLE ON THE FAIRING. SOME PIECES OF ICE FALL FROM THE ET/ORB UMBILICALS AS THE VEHICLE PASSES THE CAMERA.

OTV 163 Views ET/Orbiter umbilical and Orbiter T-0
Color M-II umbilical from the FSS.

Comments: LIGHT FROM INSIDE LH2 TSM SHINES ON ORBITER AFT FUSELAGE WHEN INTERIOR CAMERA IS ACTIVATED. SMOKE AND SPARKS FROM THE IGNITERS IS BLOWN NORTH UNDER THE BODY FLAP BY THE WIND FOLLOWED BY FREE BURNING HYDROGEN. ALTHOUGH SOME OF THE BURNING HYDROGEN IS DRAWN BACK INTO THE SSME EXHAUST HOLE BY PLUME ASPIRATION, SOME OF THE HYDROGEN RISES HIGH ENOUGH TO BE CONSUMED AND DISSIPATE. (GOOD CORRELATION WITH IR DATA). A HEAVY SHOWER OF ICE/FROST FALLS FROM THE ET/ORB UMBILICALS DURING SSME IGNITION. ALTHOUGH SEVERAL PIECES OF THE ICE ARE DRAWN INTO THE SSME EXHAUST HOLE BY PLUME ASPIRATION, NO IMPACTS TO THE BODY FLAP ARE VISIBLE. DISCONNECT AND RETRACTION OF THE LH2 T-0 UMBILICAL IS NORMAL. RESIDUAL LH2 VAPORS EXIT THE FLIGHT T-0 QD. ICE CONTINUES TO FALL FROM THE ET/ORB UMBILICALS AFTER LIFTOFF.

OTV 170 Views overall vehicle from SE direction.
Color M-II

Comments: WATER DELUGE IS ACTIVATED PROPERLY. RUSTY DELUGE WATER IS SPRAYED FROM THE SOUTH SIDE OF THE MLP. SSME IGNITION APPEARS NOMINAL. AS THE VEHICLE RISES AND THE LH WING PASSES THE HAUNCH, A BIRD ENTERS THE FOV FROM THE GENERAL FSS AREA AND APPEARS TO BE HEADING EAST. THE BIRD IS NOT NEAR THE VEHICLE.

OTV 171 Views overall vehicle from SW direction.
Color M-II

Comments: FREE BURNING HYDROGEN RISES TOWARD THE BASE HEAT SHIELD NEAR THE RH RCS STINGER. RCS PAPER COVERS TEAR OFF AND FALL INTO SSME PLUME DURING IGNITION. SSME STARTUP APPEARS NOMINAL. JUST PRIOR TO T-0, A LARGE PIECE OF RCS PAPER COVER FALLS FROM THE -Z SIDE OF THE LH STINGER.

STI (C/S 2) Infrared view from camera site 2.
B/W M-II

Comments: START OF SSME IGNITION CAUSES FREE BURNING HYDROGEN TO RISE ALONG THE RIGHT SIDE OF THE VERTICAL STABILIZER FROM SSME #1 AND DRIFT NORTH UNDER THE BODY FLAP FROM SSME #2 AND #3. THE BURNING HYDROGEN EITHER DISSIPATES OR IS DRAWN BACK INTO THE SSME PLUME BY ASPIRATION. SSME PLUMES APPEAR NORMAL. HEATING OF THE BASE HEAT SHIELD OCCURS PRIOR TO TOWER CLEAR.

STI (RSS) Infrared view from RSS roof.
B/W M-II

Comments: SSME IGNITION SEQUENCE IS CLEARLY VISIBLE - NO START UP ANOMALIES. NO FREE BURNING HYDROGEN RISES ALONG THE LEFT SIDE OF THE VEHICLE.

TV-1 Views entire launch vehicle from camera site 9
Color M-II northwest of the pad.

Comments: VIEW IS TOO DISTANT FOR DETAIL. FOCUS BECOMES BLURRED AFTER THE ROLL MANEUVER.

TV-2 Views entire launch vehicle from the convoy at SLF
Color M-II

Comments: VIEW IS TOO DISTANT FOR DETAIL. NO VEHICLE ANOMALIES.

TV-4 Views entire vehicle from Beach Road IFLOT Site.
Color M-II

Comments: THE BIRD IN OTV 170 IS NOT VISIBLE IN THIS FOV. AT GMT 00:24:08.588, A WHITE STREAK OR VAPOR STREAM APPEARS AFT OF THE RH WING. A PARTICLE FALLS OUT OF THE PLUME AT GMT 00:25:23.897 FOLLOWED BY NUMEROUS PARTICLES SOON AFTER. SRB SEPARATION APPEARS NOMINAL. MANY CLINKERS APPEAR IN THE SRB PLUMES AFTER SEPARATION.

TV-5 Views launch from VAB roof.
Color M-II

Comments: VIEW IS TOO DISTANT FOR DETAIL. NO VEHICLE ANOMALIES ARE VISIBLE. SRB SEPARATION APPEARS NORMAL. NUMEROUS CLINKERS FALL FROM THE SRB PLUMES AFTER SRB SEPARATION.

TV-7 Views entire launch vehicle from camera site 2
Color M-II east of pad.

Comments: FREE BURNING HYDROGEN IS BLOWN NORTH UNDER THE BODY FLAP. A BIRD IS FIRST VISIBLE AT GMT 00:23:33.288 OVER THE RSS ROOF AND APPEARS TO BE MOVING EAST OR NORTHEAST. AN OBJECT LEADS THE SRB EXHAUST PLUME OUT OF THE FLAME TRENCH AT GMT 00:23:32.918.

TV-11 Views launch vehicle from SLF Tower #1.
Color M-II

Comments: VIEW IS TOO DISTANT FOR DETAIL. NO VEHICLE ANOMALIES.

TV-13 Cocoa Beach DOAMS video. Tracks launch vehicle
Color M-II from acquisition to LOV.

Comments: PLUME RECIRCULATION STARTS AT GMT 00:25:05.752. NUMEROUS PARTICLES APPEAR FROM THE SRB PLUMES AT GMT 00:25:35.75. SRB SEPARATION OCCURS AT 00:25:36.815 AND APPEARS NOMINAL. NUMEROUS CLINKERS FALL OUT OF THE SRB PLUMES AFTER SEPARATION.

TV-16 View from helicopter orbiting west of pad and VAB.
Color M-II

Comments: VIEW IS TOO DISTANT FOR DETAIL AND TRACKING IS ERRATIC

TV-18 Malabar ITEC video. Tracks launch vehicle from
Color M-II acquisition to LOV.

Comments: FOCUS IS SOFT DUE TO ATMOSPHERIC EFFECTS. PLUME RECIRCULATION IS NORMAL. SRB SEPARATION APPEARS NORMAL. NUMEROUS CLINKERS FALL FROM THE SRB PLUMES AFTER SEPARATION.

TV-21 Views entire launch vehicle from DLTR-3 site
Color M-II directly south of Pad B.

Comments: INITIAL LIFTOFF IS OBSCURED BY SSME PLUME (STEAM CLOUD). VIEW IS TOO DISTANT FOR DETAIL. VEHICLE ASCENT IS THEN OBSCURED BY SRB PLUME.

ET-204 Patrick IGOR video. Tracks launch vehicle from
Color M-II acquisition to LOV.

Comments: VIEW IS UNDEREXPOSED AND ONLY THE PLUME IS VISIBLE. PLUME RECIRCULATION NEAR THE ET AFT DOME IS NORMAL. CLINKERS APPEAR IN THE SRB PLUMES PRIOR TO AND AFTER SRB SEPARATION.

ET-206 Melbourne Beach ROTI video. Tracks launch vehicle
Color M-II from acquisition to LOV.

Comments: NOT MUCH VEHICLE DETAIL DUE TO UNDEREXPOSURE. PLUME RECIRCULATION NEAR THE ET AFT DOME IS TYPICAL. CLINKERS APPEAR IN THE SRB PLUMES BEFORE AND AFTER SRB SEPARATION.

ET-207 UCS-10 MIGOR video. Tracks launch vehicle from
Color M-II acquisition to LOV.

Comments: FSS WATER DELUGE IS BLOWN NORTH BY THE WIND. WATER FROM SRB STIFFENER RINGS AND CONDENSATE ON ET AFT DOME VAPORIZE AFTER LIFTOFF. VEHICLE OVERSHOTS SLIGHTLY DURING ROLL PROGRAM. AT GMT 00:24:30.615, A LIGHT-COLORED, ELONGATED (DUE TO SLOW FRAME RATE STREAKING) OBJECT, PROBABLY A PIECE OF BURNING SRB PROPELLANT AND/OR INHIBITOR, APPEARS TO DROP OUT OF RH SRB PLUME NEAR THE AFT SKIRT AREA. CLINKERS APPEAR IN THE SRB PLUMES AFTER SEPARATION.

ET-208 Cocoa Beach DOAMS video. Tracks launch vehicle
Color M-II from acquisition to LOV.

Comments: NO OBJECTS FALL AFT OF THE SSME AREA. PLUME RECIRCULATION NEAR THE ET AFT DOME IS A NORMAL OCCURRENCE. CLINKERS APPEAR IN THE SRB PLUMES BEFORE AND AFTER SEPARATION. FWD BSM'S FIRE ONE FRAME AFTER THE AFT BSM'S FIRE.

ET-212 UCS-23 MIGOR video. Tracks launch vehicle from
Color M-II acquisition to LOV.

Comments: MOMENTARY WHITE TRAIL STREAMING AFT OF THE RUDDER/
SPEED BRAKE SPLIT MAY BE CONDENSATE RUN-OFF FROM THE TRAILING
EDGE (OCCURS 28 SECONDS AFTER ACQUISITION). LOCAL SUPERSONIC FLOW
CONDENSATION FORMS ON THE VEHICLE SOON AFTER THIS EVENT. NUMEROUS
(OVER 100) CLINKS APPEAR IN THE SRB PLUMES BEFORE AND AFTER SRB
SEPARATION.

ET-213 UCS-7 MOTS video. Tracks launch vehicle from
Color M-II acquisition to LOV.

Comments: VEHICLE OVERSHOOTS SLIGHTLY DURING ROLL PROGRAM. VIEW
BECOMES DISTANT AND TRACKING ERRATIC AFTER ROLL MANEUVER.

6.2 ON-ORBIT FILM DATA REVIEW

No photographs were taken of the External Tank after separation due to the orbital position in the Earth's shadow.

6.3 LANDING FILM DATA REVIEW

E-1001 Orbiter landing at Ames-Dryden Flight Research
16mm Facility

Focus : SOFT DUE TO ATMOSPHERIC EFFECTS

F. O. V.: OK

Exposure: VEHICLE IS BACKLIT BY THE SUN

Comments: EXTENSION OF THE RH MLG SLIGHTLY LAGS THE LH SIDE.
THIS HAS BEEN OBSERVED PREVIOUSLY ON OTHER ORBITERS. MAIN LANDING
GEAR TOUCHDOWN AND VEHICLE ROLLOUT ARE OBSCURED BY BUILDINGS.

E-1002 Orbiter landing at Ames-Dryden Flight Research
16mm Facility

Focus : OK

F. O. V.: OK

Exposure: OK

Comments: VIEW IS TOO DISTANT FOR DETAIL. MAIN LANDING GEAR
TOUCHDOWN AND VEHICLE ROLLOUT ARE OBSCURED BY BUILDINGS.

E-1005 Orbiter landing at Ames-Dryden Flight Research
35mm Facility

Focus : OK

F. O. V.: OK

Exposure: OVEREXPOSED DUE TO SUN'S POSITION

Comments: ORBITER IS BACKLIT DURING FINAL APPROACH. RH MLG WHEEL
CONTACTS RUNWAY FIRST. NO VEHICLE OR TPS ANOMALIES.

E-1006 Orbiter landing at Ames-Dryden Flight Research
35mm Facility

Focus : SOFT

F. O. V.: OK

Exposure: OK

Comments: ORBITER IS BACKLIT BY SUN'S POSITION. RH MLG WHEEL
CONTACTS RUNWAY FIRST. NO VEHICLE OR TPS ANOMALIES.

E-1008 Orbiter landing at Ames-Dryden Flight Research
35mm Facility

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: ORBITER IS BACKLIT BY SUN'S POSITION. LH WING IS
SLIGHTLY LOW TO COMPENSATE FOR CROSSWIND. ALTHOUGH ORBITER WINGS
RETURN TO LEVEL POSITION, RH MAIN LANDING GEAR WHEEL CONTACTS
RUNWAY FIRST. NO VEHICLE OR TPS ANOMALIES.

E-1009 Orbiter landing at Ames-Dryden Flight Research
16mm Facility

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: ORBITER IS BACKLIT BY SUN'S POSITION. EXTENSION OF RH
MAIN LANDING GEAR SLIGHTLY LAGS THE LEFT SIDE AS PREVIOUSLY
OBSERVED ON OTHER ORBITERS. NO VEHICLE OR TPS ANOMALIES.

E-1017 Orbiter landing at Ames-Dryden Flight Research
16mm Facility

Focus : OK
F. O. V.: UNSTEADY
Exposure: OK

Comments: HAND HELD CAMERA IS VERY SHAKY AND PREVENTS RESOLUTION
OF DETAIL.

E-1019 Orbiter landing at Ames-Dryden Flight Research
16mm Facility

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: HAND HELD CAMERA IS VERY SHAKY AND PREVENTS RESOLUTION
OF DETAIL.

7.0 SRB POST FLIGHT/RETRIEVAL DEBRIS ASSESSMENT

Both Solid Rocket Boosters were inspected for debris damage and debris sources at CCAFS Hangar AF on 26 November 1989 from 0800 to 1200 hours. In general, the SRB's appeared to be in good condition.

7.1 RH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The nose cap was not recovered. The RH frustum was missing no MSA-2 TPS but exhibited ten debonds, all of which measured approximately 1 inch in diameter. The Hypalon paint had blistered slightly in localized areas (Figure 7). The four BSM aero heat shield covers had locked in the 180 degree open position, but the attach rings were bent causing three of the covers to be positioned (with respect to the nozzle exit plane) at 90 degrees and one positioned at 180 degrees. Aero heat shield mounting fasteners were missing or deformed. Some of the parachute risers had been entangled in this area and were cut by the recovery team.

The RH forward skirt exhibited one debond measuring 1/2"x1/4", but no missing TPS. Some layers of MSA adhered to the blistered Hypalon paint forward of the attach fitting (Figure 8). The phenolic plate on the -Z RSS antenna had delaminated and some of the material was missing. Cork erosion (4"x2"x1/8") and exposed metal (1"x1/4") had occurred on the aft surface of the ET/SRB forward attach point electrical disconnect box. Separation of the forward attach fitting was nominal and the RSS cables separated cleanly. RSS crossover closeouts at the +Z corners of the transition tunnel were incomplete/missing per view DD-DD, Sheet 13, Dwg 10100-0059. Drawing allows use of K5NA or RTV-133 for the closeout.

Known void areas on the field joint closeouts and repairs remained intact. Minor trailing edge damage to the GEI cork runs was attributed to debris hits from nozzle extension severance. The forward segment factory joint EPDM moisture seal was debonded in two locations along the leading edge (15"x1.5" deep at the 160 degree radial location, 1/2 inch long at the 270 degree location) and one location along the trailing edge (1.5 inches long at 210 degrees).

Little instafoam was lost from the three stiffener rings at splashdown. K5NA closeouts on the IEA covers were intact, but the Hypalon paint was slightly blistered. One electrical connector on the upper strut was slightly deformed. Minor damage on the stub ring was attributed to water impact.

The phenolic material on the kick ring delaminated in some locations. K5NA thermal protective domes were missing from bolt heads on the aft side of the kick ring and uncovered substrate was sooted. K5NA was also missing from all four aft BSM

FIGURE 7. RIGHT SRB FRUSTUM

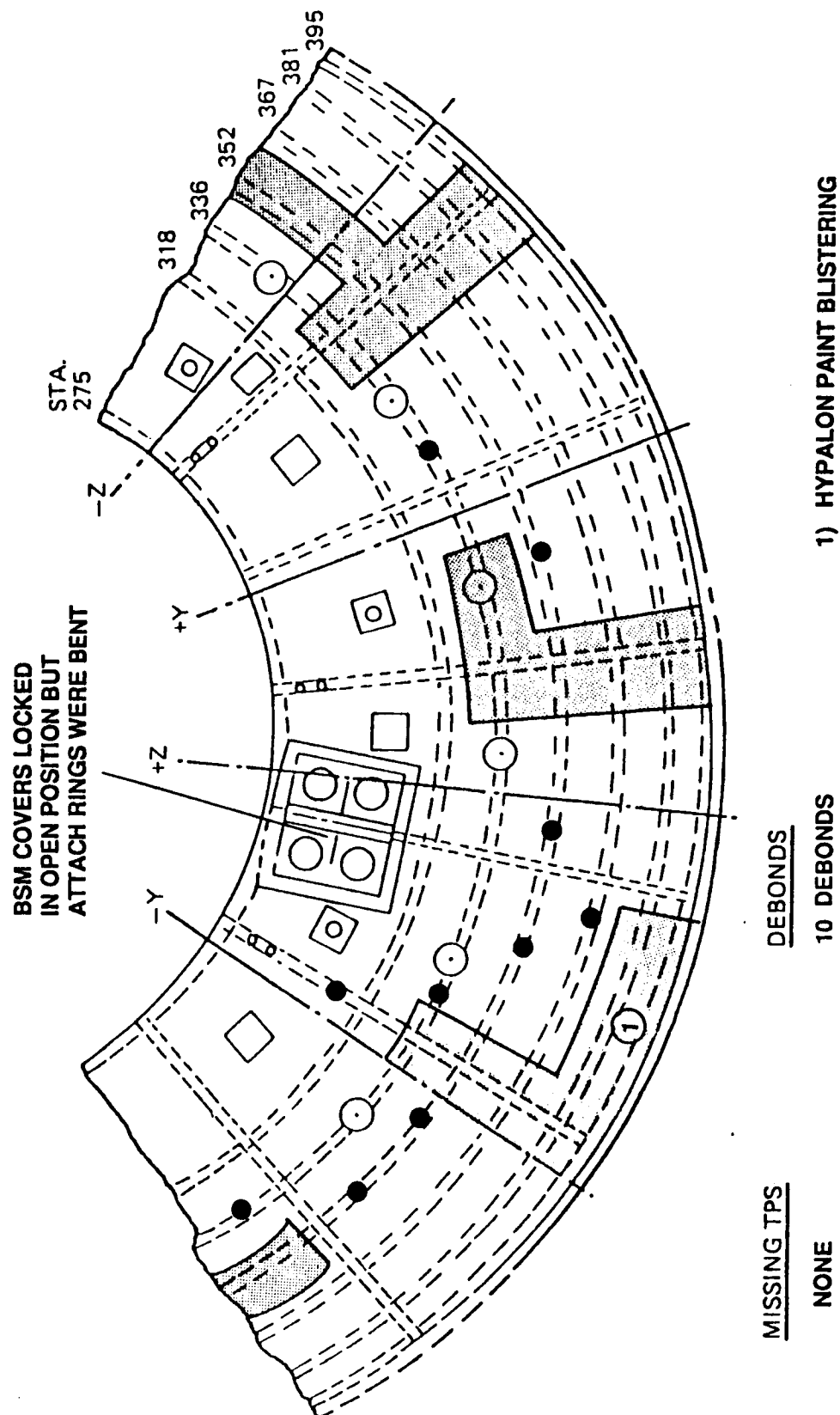
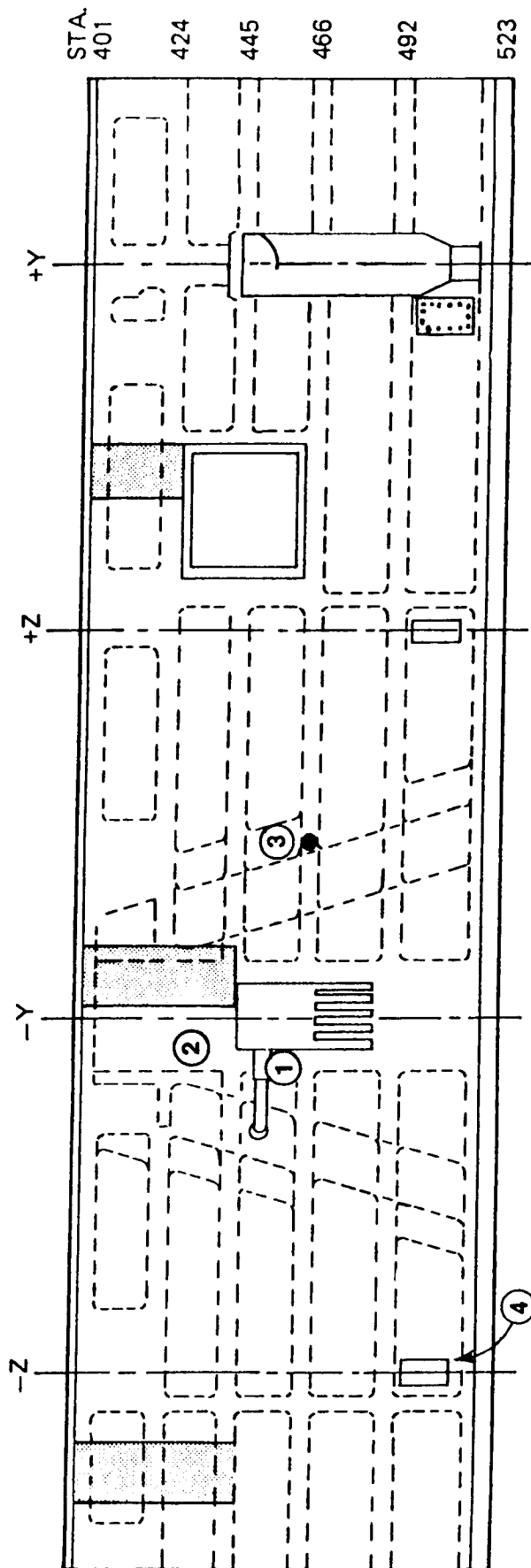


FIGURE 8. RIGHT SRB FWD SKIRT



TPS MISSING

- 1) CORK MISSING ON DISCONNECT
ASSY. 2" X 4"

DEBONDS

- 3) 1/2" X 1/4"
- 4) DELAMINATED
PHENOLIC PLATE

- 2) HYPALON PAINT BLISTERING

nozzles. The TPS over the aft skirt acreage was generally in good condition (Figure 9). Instafoam was missing from the aft ring around the aft skirt feet, HPU exhaust horns, and joint heater umbilical. K5NA was missing from the inboard edge of all aft skirt feet. Safety wire was missing from the HDP #1 and #2 debris containment assemblies.

NSI cartridge fragments and a sliver of frangible nut were wedged between the debris plunger and the spherical washer on HDP #2. Three small pieces of shim material were wedged in the bore against the HDP #4 debris plunger.

Holddown post #3 aft skirt foot hole (bore) showed evidence of stud 'hang-up'. Thread marks from the Inconel stud were impressed around the forward inner aluminum surface of the hole. The stud abraded a 1/2-inch deep chamfer inclined 45 degrees on the inboard aft edge of the hole, and some of the paint from the inner surface of the hole was removed by the broaching. The aft facing surface of the foot was charred by ascent heating where 40 percent of the shim material had been pulled from the foot at liftoff by the stud.

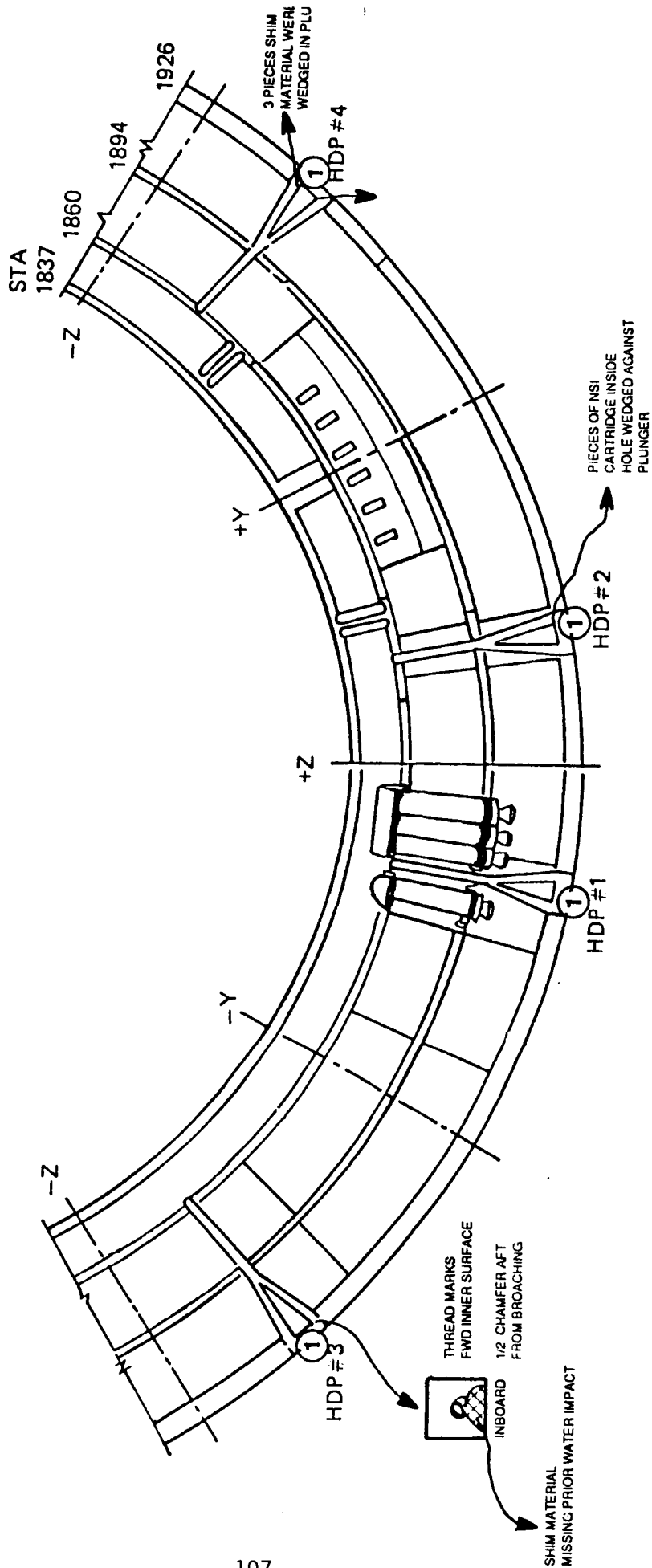
Stud hang-ups have occurred on six previous flights (STS-2, 4, 51-I, 51-J, 61-A, and 34). Holddown post shoes have been lifted on STS-2, 29, and 34, but did not occur on this holddown post. Further investigation revealed HDP #3 stud preload limits were within specification just prior to liftoff.

7.2 LH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The nose cap was not recovered. The LH frustum exhibited 10 debonds and no missing MSA-2. There was minor blistering of the Hypalon paint along the entire circumference of the aft ring frame (Figure 10). The BSM aero heatshield covers had locked in the 180 degree open position, but the attach rings were bent causing two of the covers to be positioned at 90 degrees to the nozzle exit plane, one at 70 degrees, and the fourth at 135 degrees. Aero heat shield mounting fasteners were missing or deformed. This condition was probably caused by parachute riser entanglement.

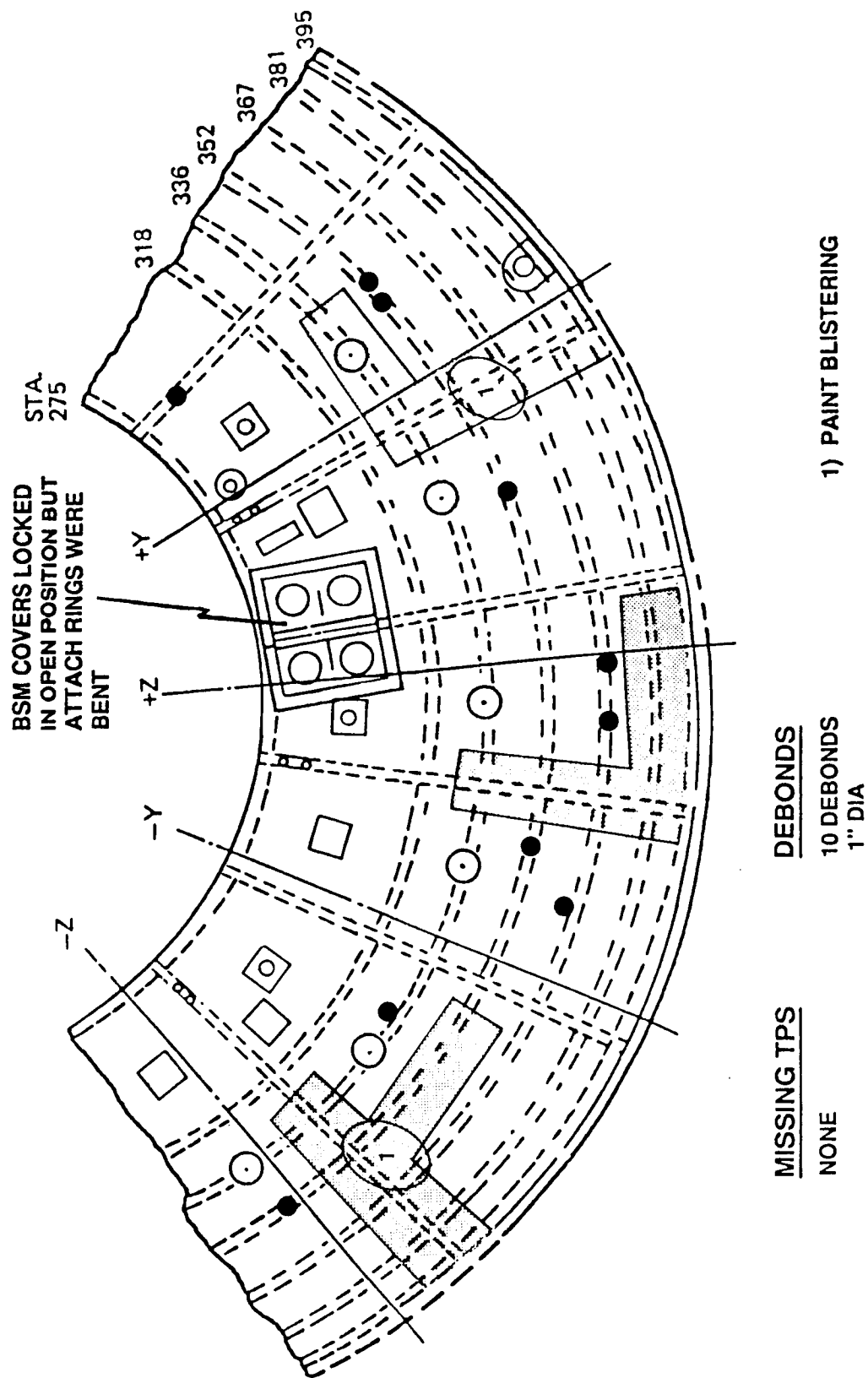
The LH forward skirt exhibited no debonds or areas of missing TPS. Minor blistering of the Hypalon paint had occurred near the forward ET/SRB thrust post (Figure 11). The phenolic plate on the +Z RSS antenna was delaminated, but no material was missing. RSS crossover closeouts at the +Z corners of the transition tunnel were incomplete or missing. Cork was eroded in a 5"x2"x1/8" area on the aft surface of the ET/SRB forward attach point electrical disconnect box. Separation of the forward attach fitting was nominal and the RSS cables separated cleanly.

FIGURE 9. RIGHT SRB AFT SKIRT EXTERIOR TPS



1) K5NA MISSING

FIGURE 10. LEFT SRB FRUSTUM



10



The aft field joint exhibited two cracks at the 45 degrees radial position where the trunnion had been potted in with K5NA. The 2-inch long cracks were parallel 1.25 inches apart and the material between the cracks could be depressed by moderate hand pressure. The trailing edge of the aft segment factory joint EPDM moisture seal showed discontinuous debonds around the entire circumference and measured 2.5 inches deep in some places. Trailing edge damage to the GEI cork runs was attributed to debris hits from the nozzle extension severance.

Water impact damage to the instafoam on the three stiffener rings was less than usual. K5NA closeouts on the IEA covers were intact, but the Hypalon paint exhibited some blistering. Instafoam was missing from the aft side of the ETA ring behind the IEA. Broken foam and exposed cork substrate were sooted. The area of missing foam measured 3 feet long by the width of the ETA ring. Separation of the aft ET/SRB struts was nominal.

Phenolic material on the kick ring was torn and delaminated in some places. K5NA was missing from all four aft BSM nozzles. The TPS acreage areas on the aft skirt were in good condition (Figure 12). Instafoam was missing from the aft ring around the holddown post shoes, the HPU exhaust horns, and the joint heater umbilical. K5NA was missing from the inboard edge of all aft skirt feet. Safety wire was missing from HDP #5 and #6. No shim material was missing from HDP #7 and #8 prior to water impact. All plungers in the debris containment assemblies had seated properly.

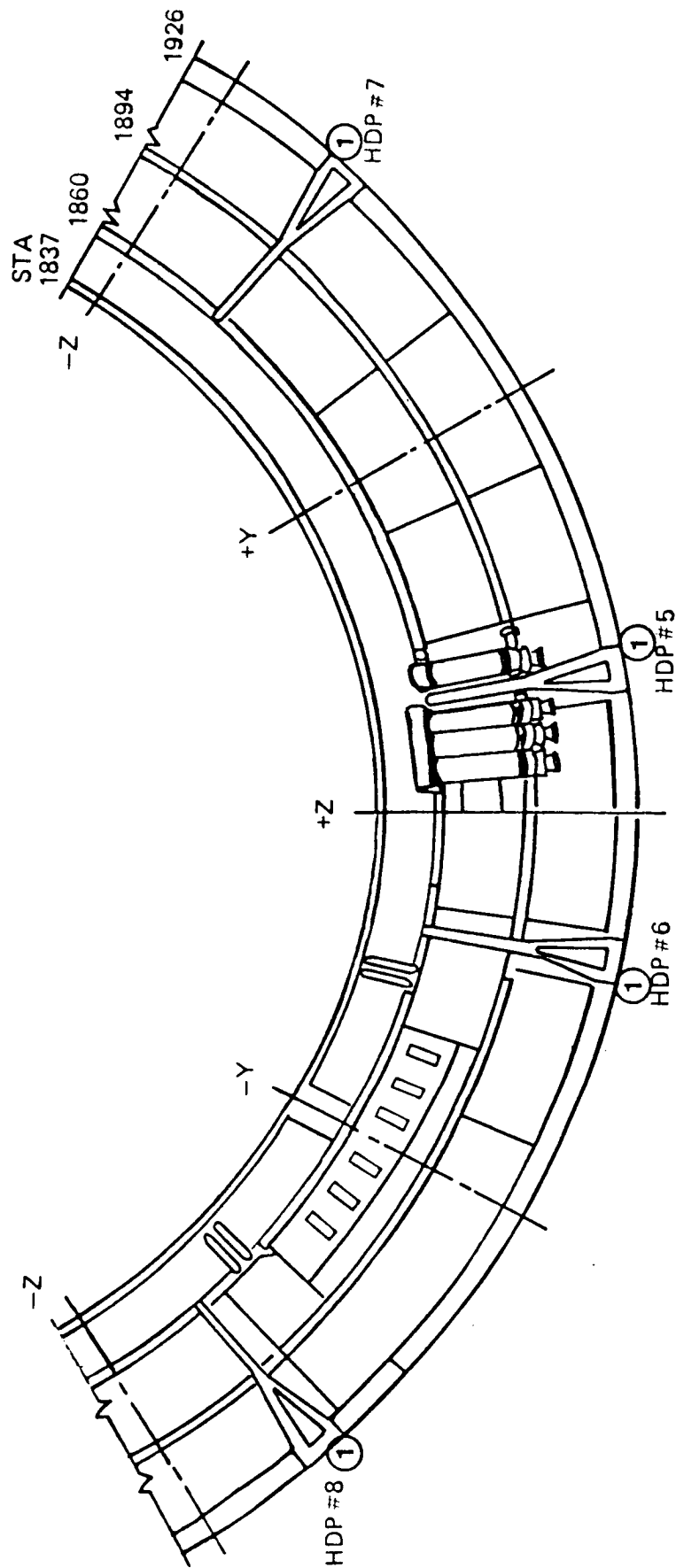
7.3 RECOVERED SRB DISASSEMBLY FINDINGS

Disassembly of the SRB's was delayed 24 hours due to bad weather in the recovery area. There was no significant quantities of sea water found in the forward skirts. Major findings to date include forward BSM doors locked in the 180 position but bent to various open positions by parachute riser entanglement. The aft skirt HDP #3 stud hole (bore) was broached due to the stud hang-up at liftoff. Five factory joint EPDM moisture seals debonds were detected - four on the LH SRB and 1 on the RH SRB. K5NA bolt head thermal protective domes on the right hand kick ring phenolic trailing edge were again missing with sooted substrate.

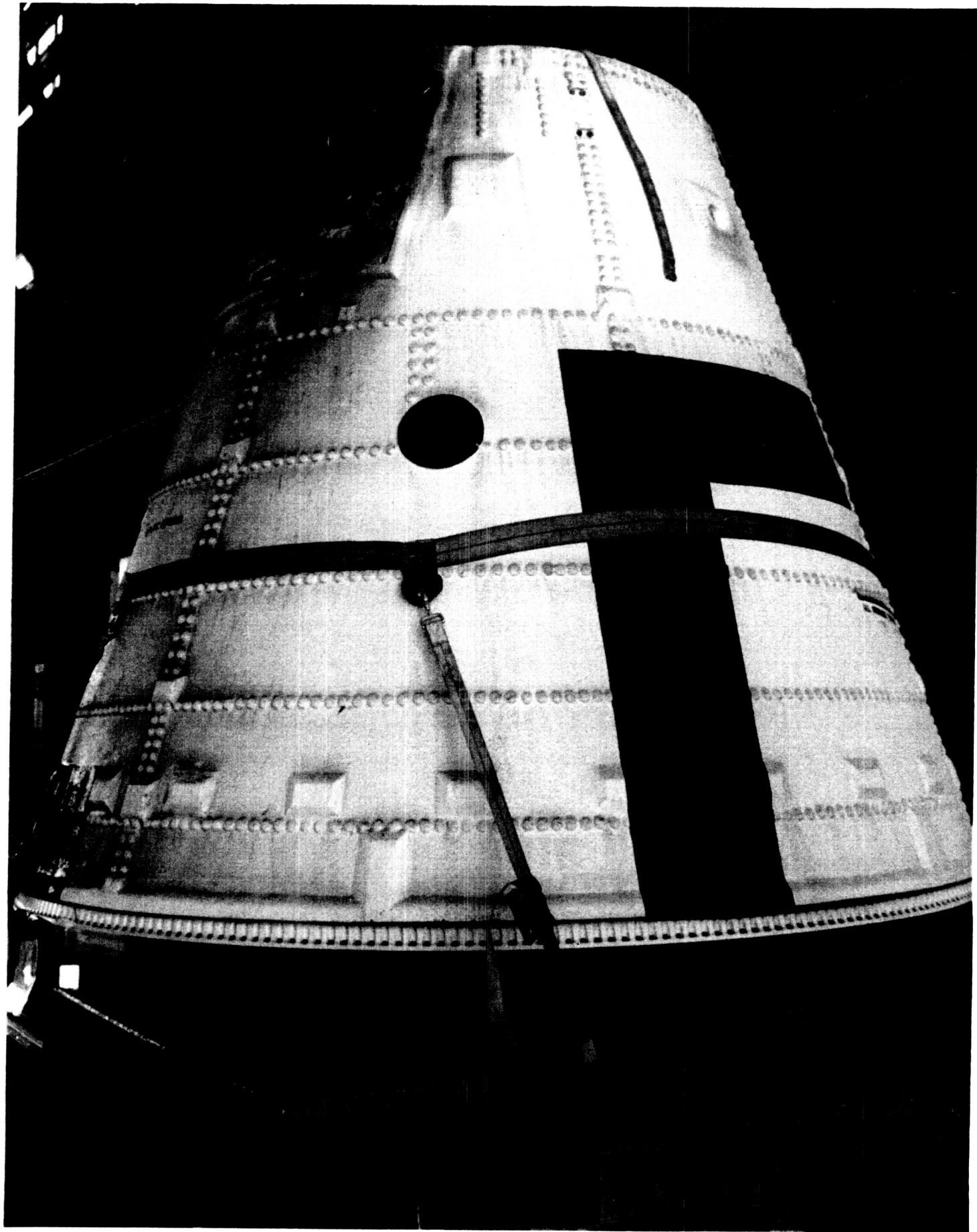
Frangible nuts from holddown posts #3, 4, and 8 exhibited a smooth fracture on one side of the separation plane with no fragmented webs on that particular side. This condition has not been observed since return to flight.

Post launch anomalies are listed in Section 10.3.

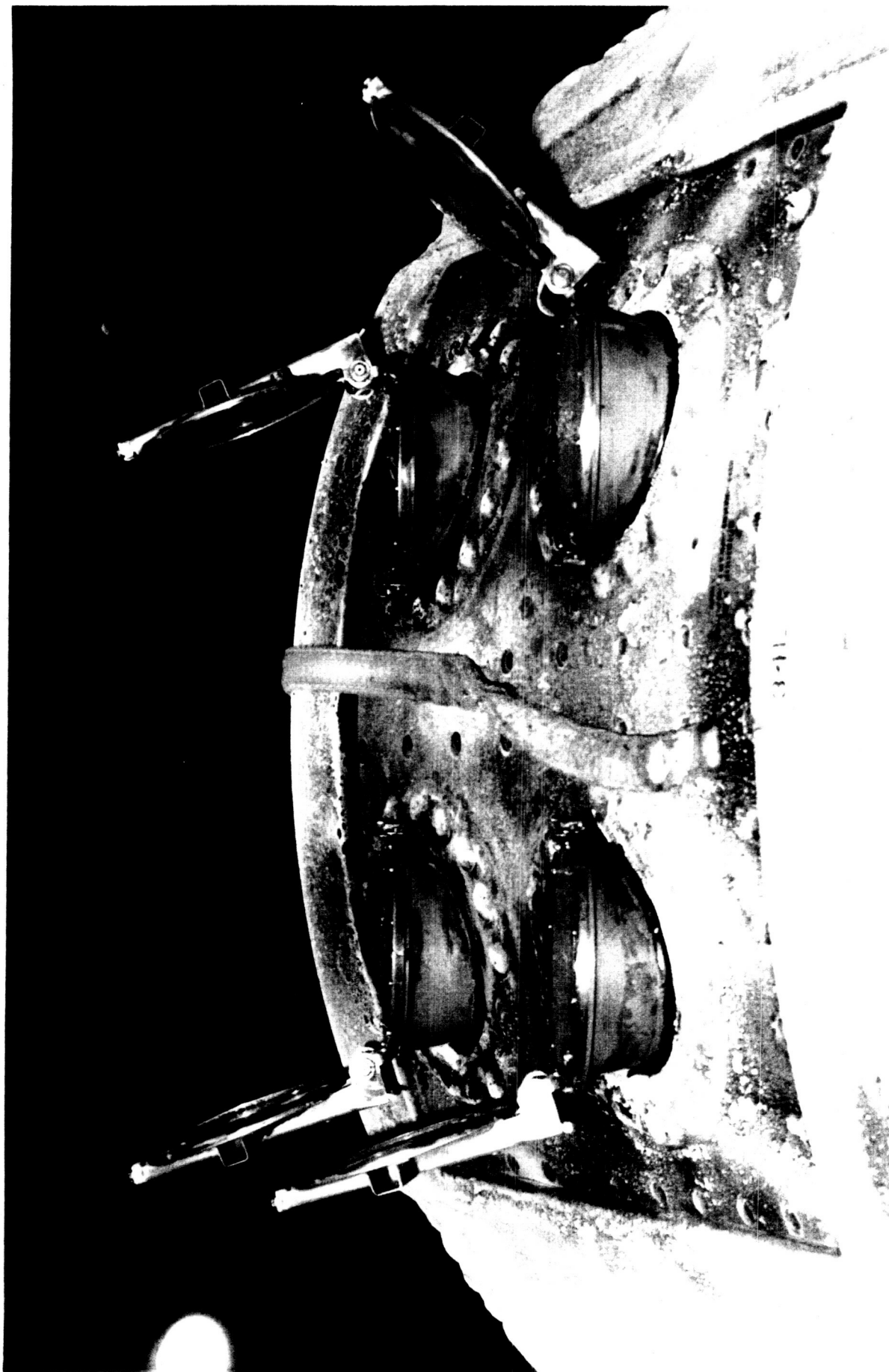
FIGURE 12. LEFT SRB AFT SKIRT EXTERIOR TPS



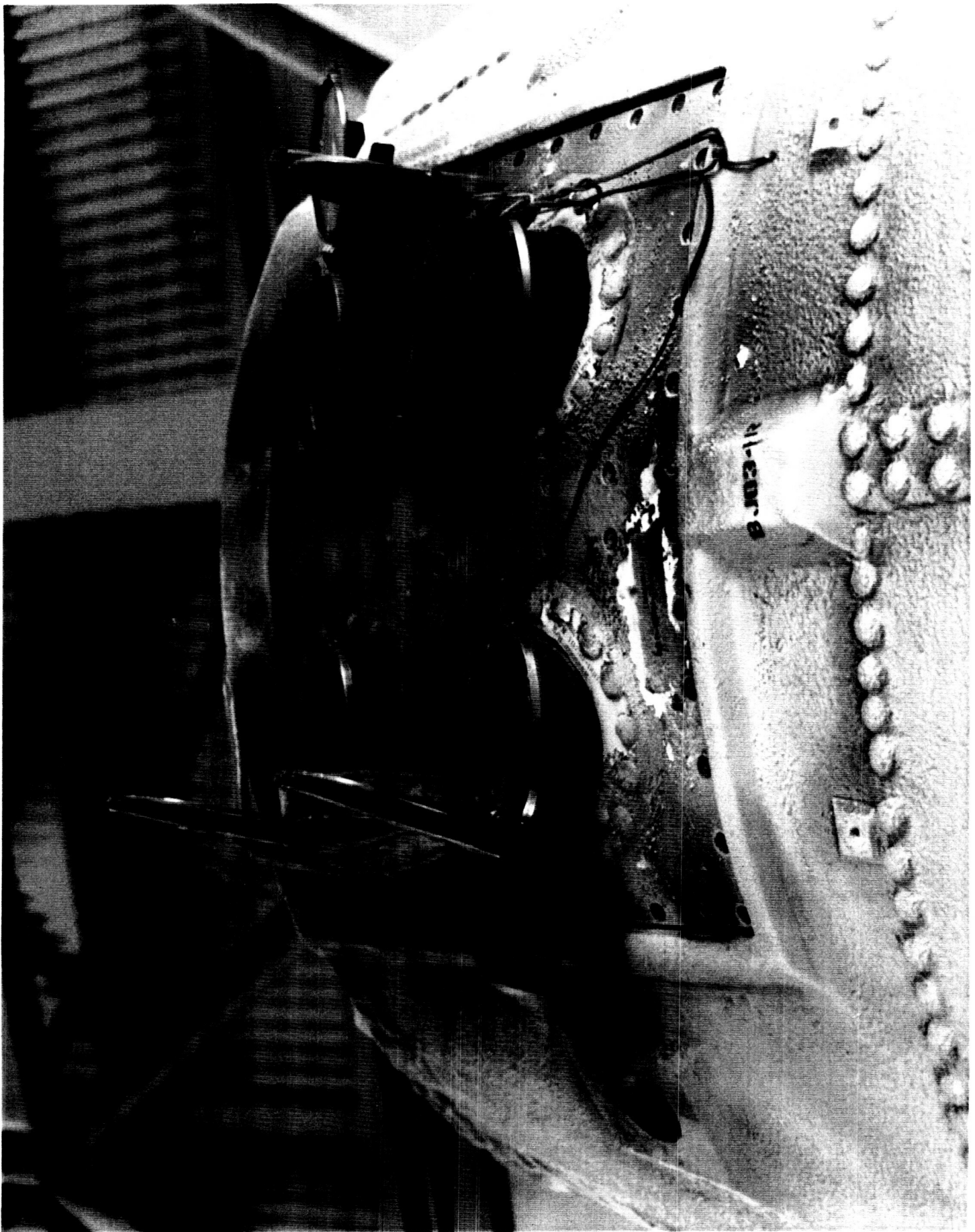
1) K5NA C/O MISSING



Overall view of RH SRB frustum. Blistering of the
Hypalon paint was minimal.



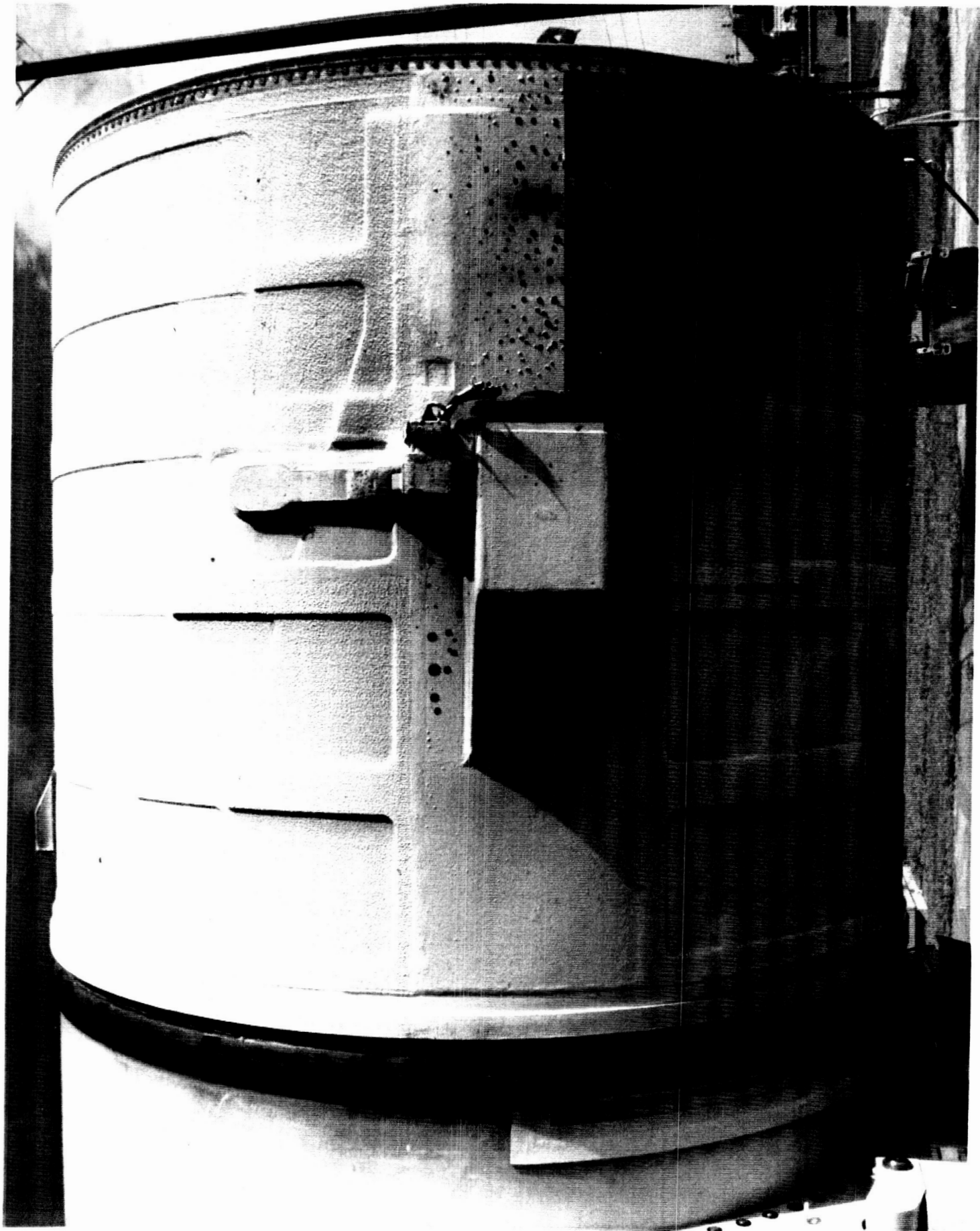
BSM aero heat shield covers on the LH frustum exhibited
bent attach rings due to parachute riser entanglement



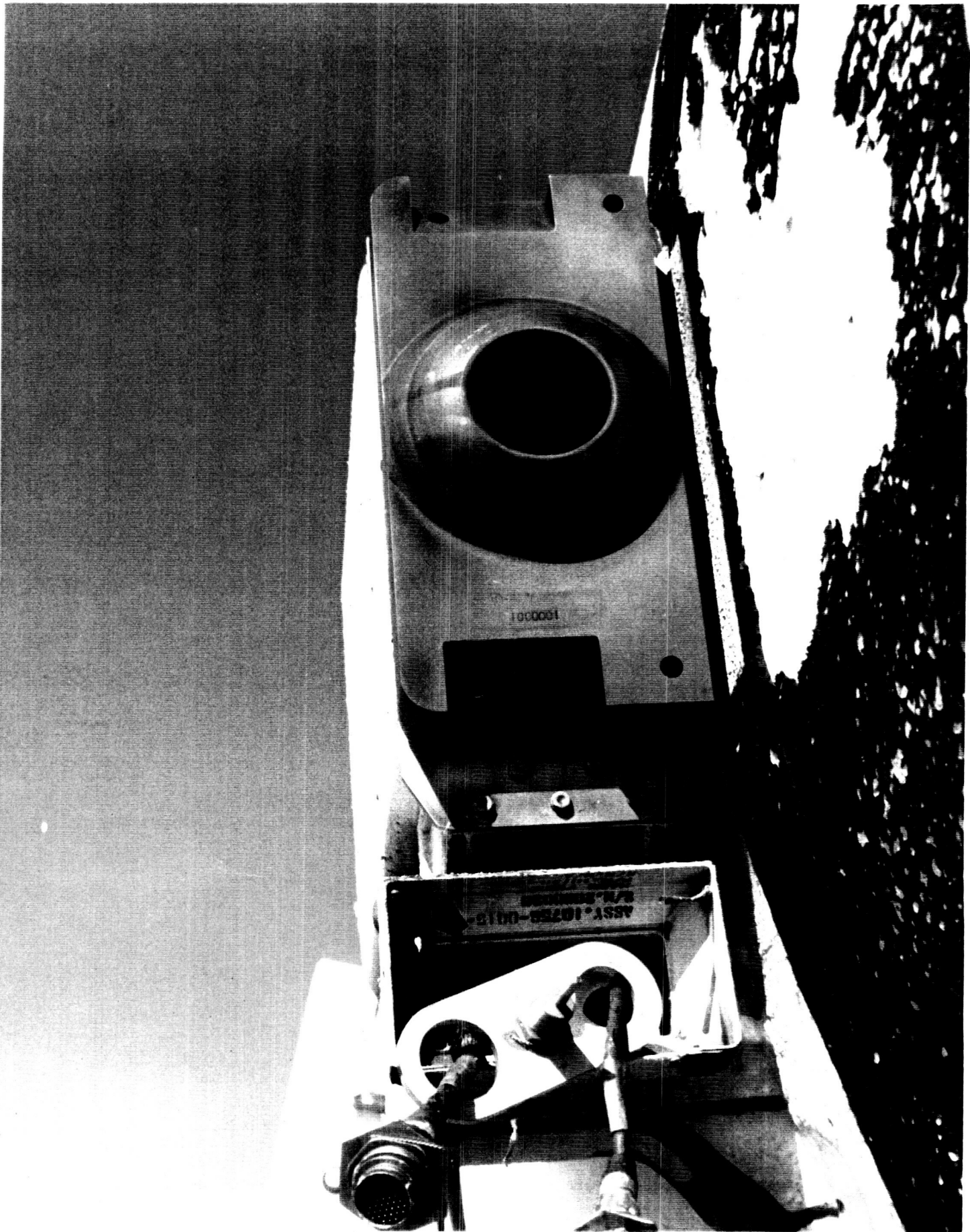
BSM aero heat shield covers on the RH frustum exhibited bent attach rings due to parachute riser entanglement



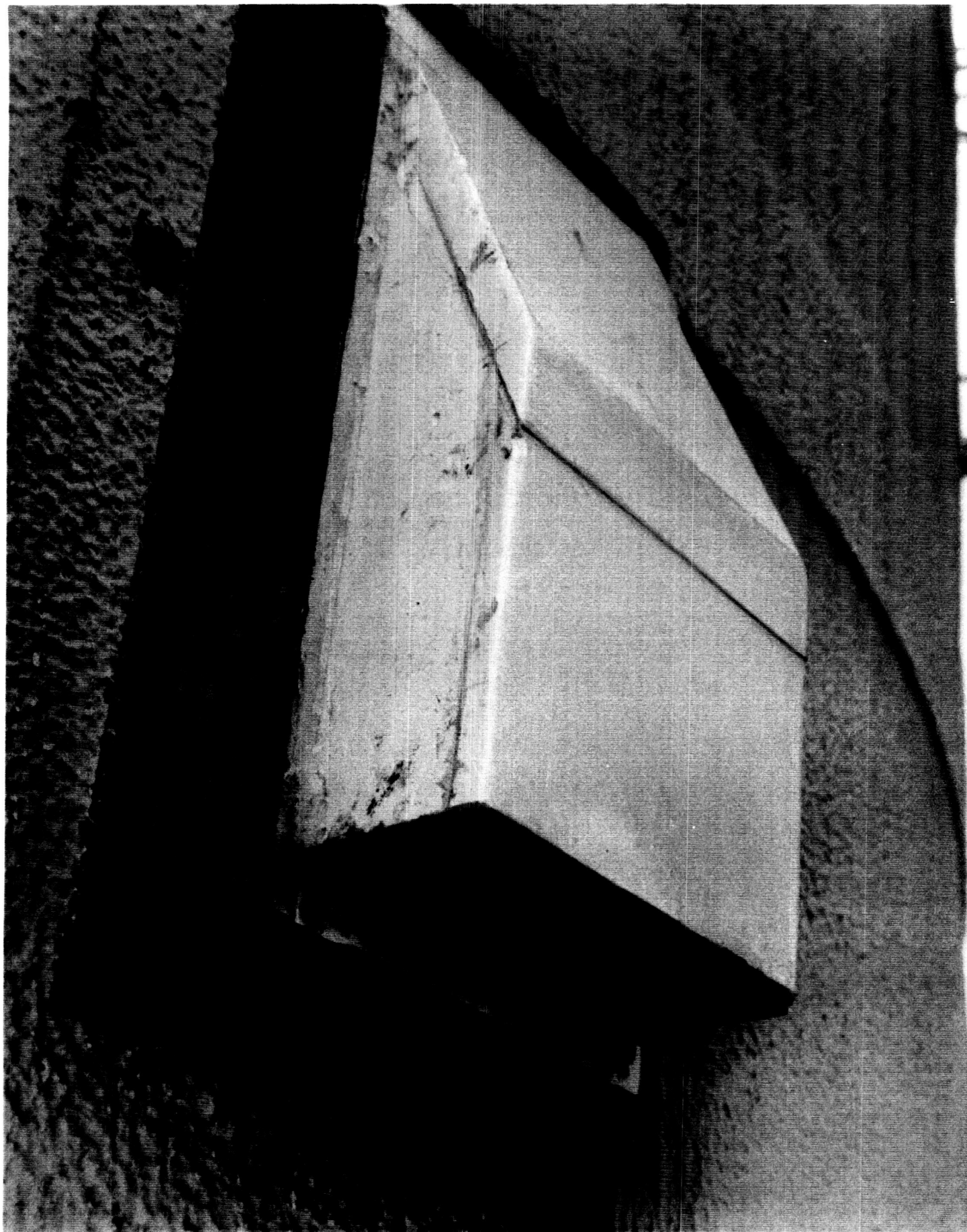
Close-in view of bent attach rings on forward BSM aero
heat shield covers



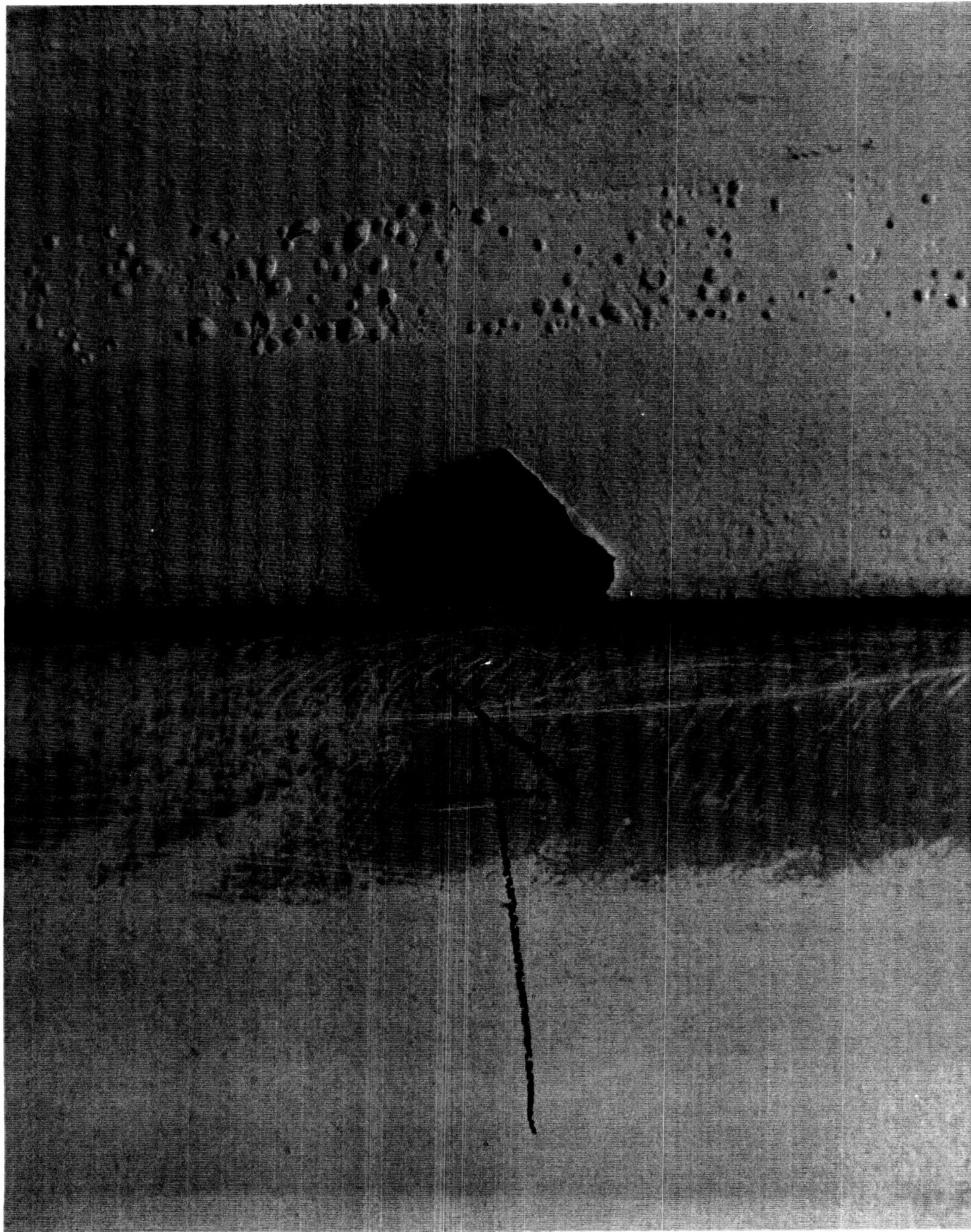
Overall view of the SRB forward skirt shows blistering of the
Hypalon paint with attached (delaminated) layers of MSA



K5NA closeout material was not applied to the corners of
the RSS crossover transition tunnel



The phenolic plate on the RSS antenna was delaminated
and some material was missing



Divot in cork closeout material showed sooted substrate



Debonded factory joint EPDM moisture seal due to poor
paint adhesion

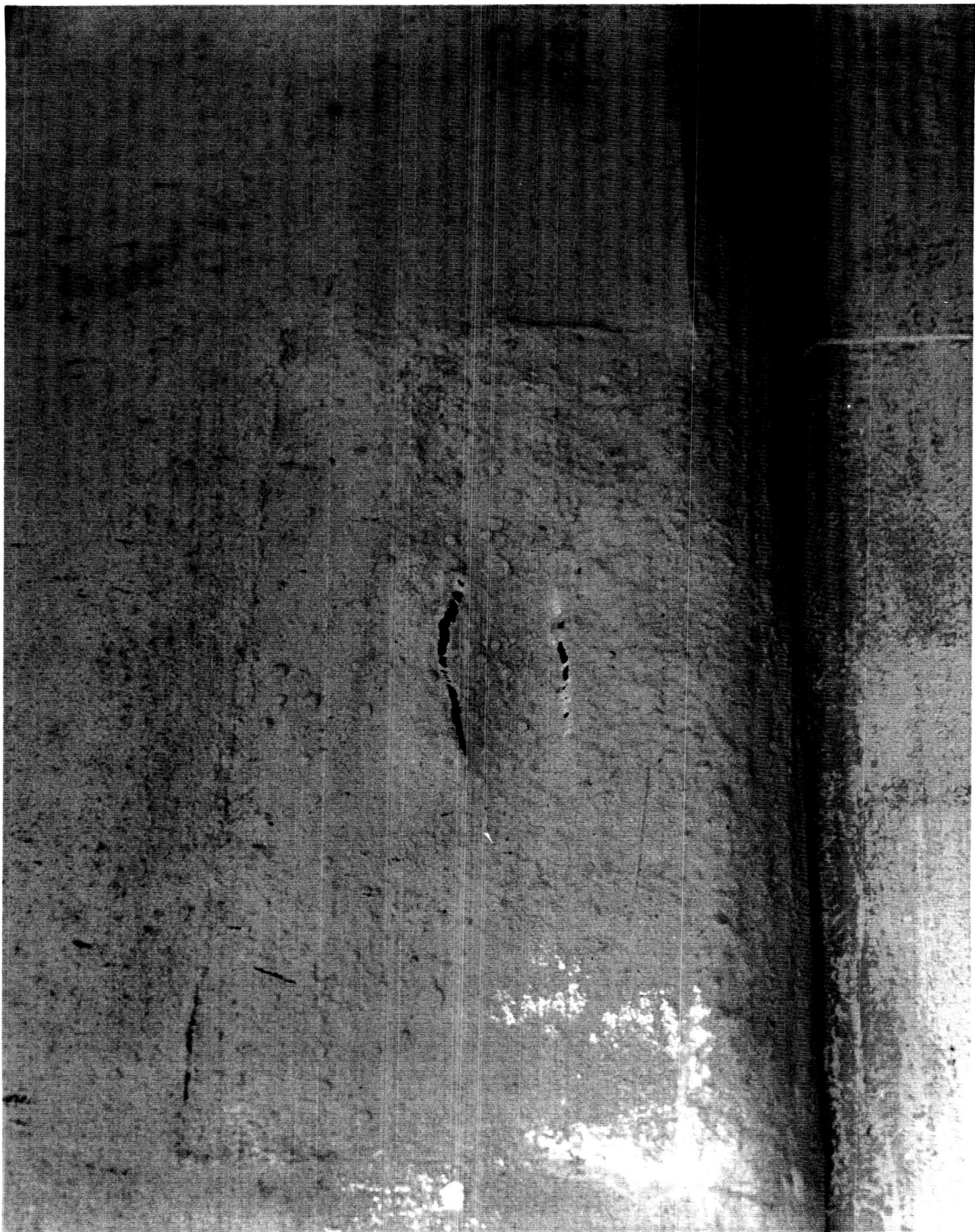
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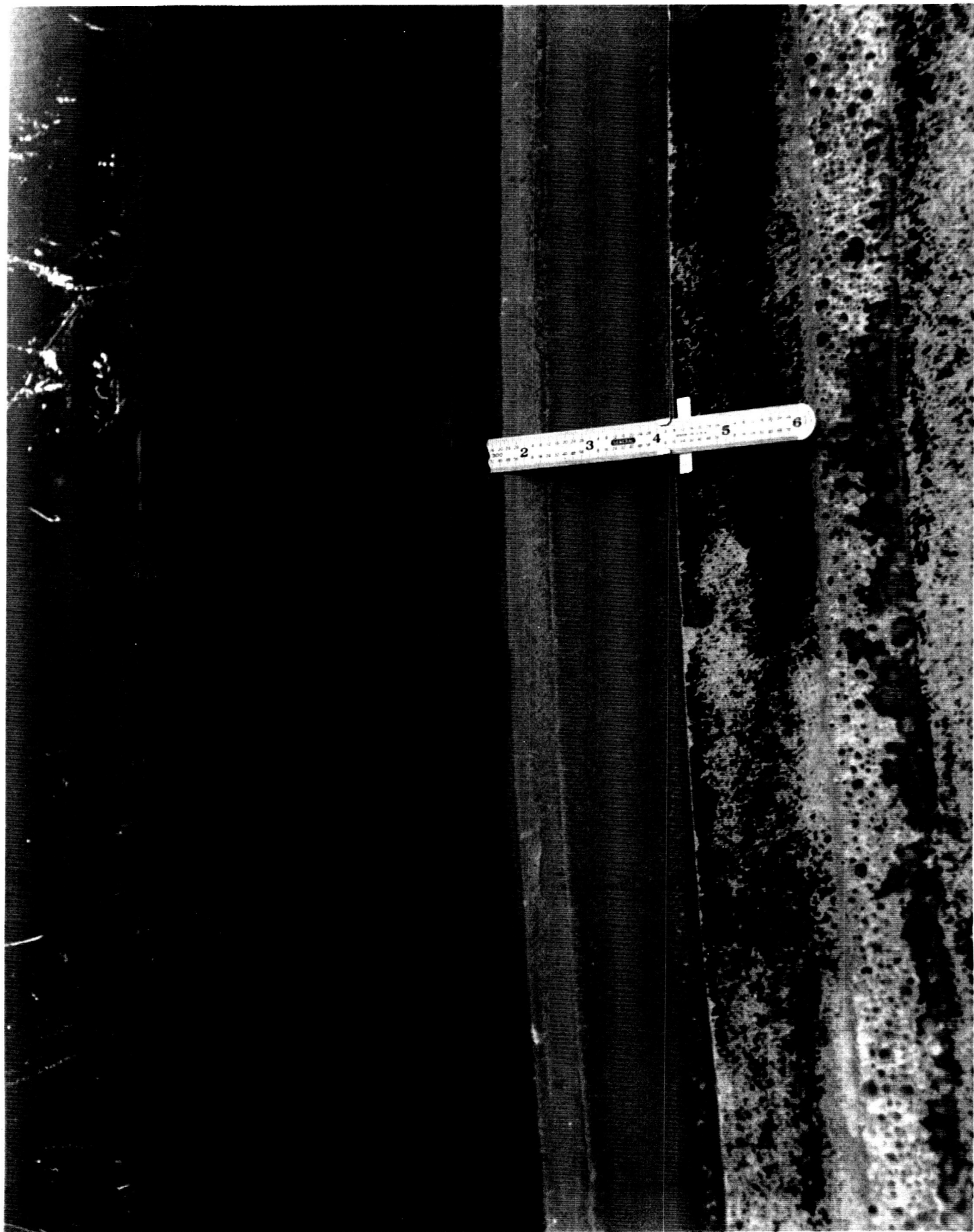
Overall view of RH SRB aft booster segment



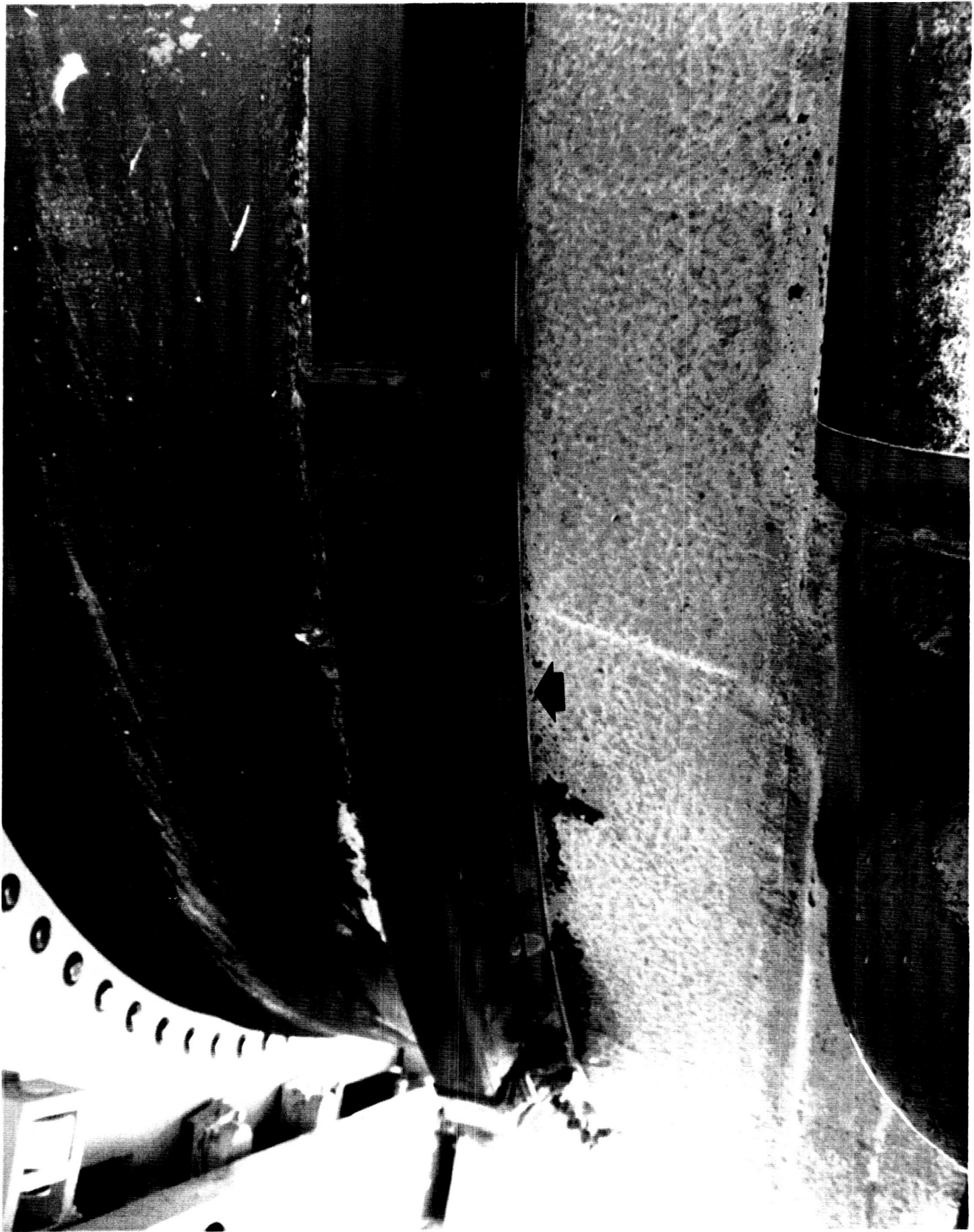
Missing Instafoam and sooted substrate occurred on the
aft side of the ETA ring behind the IEA



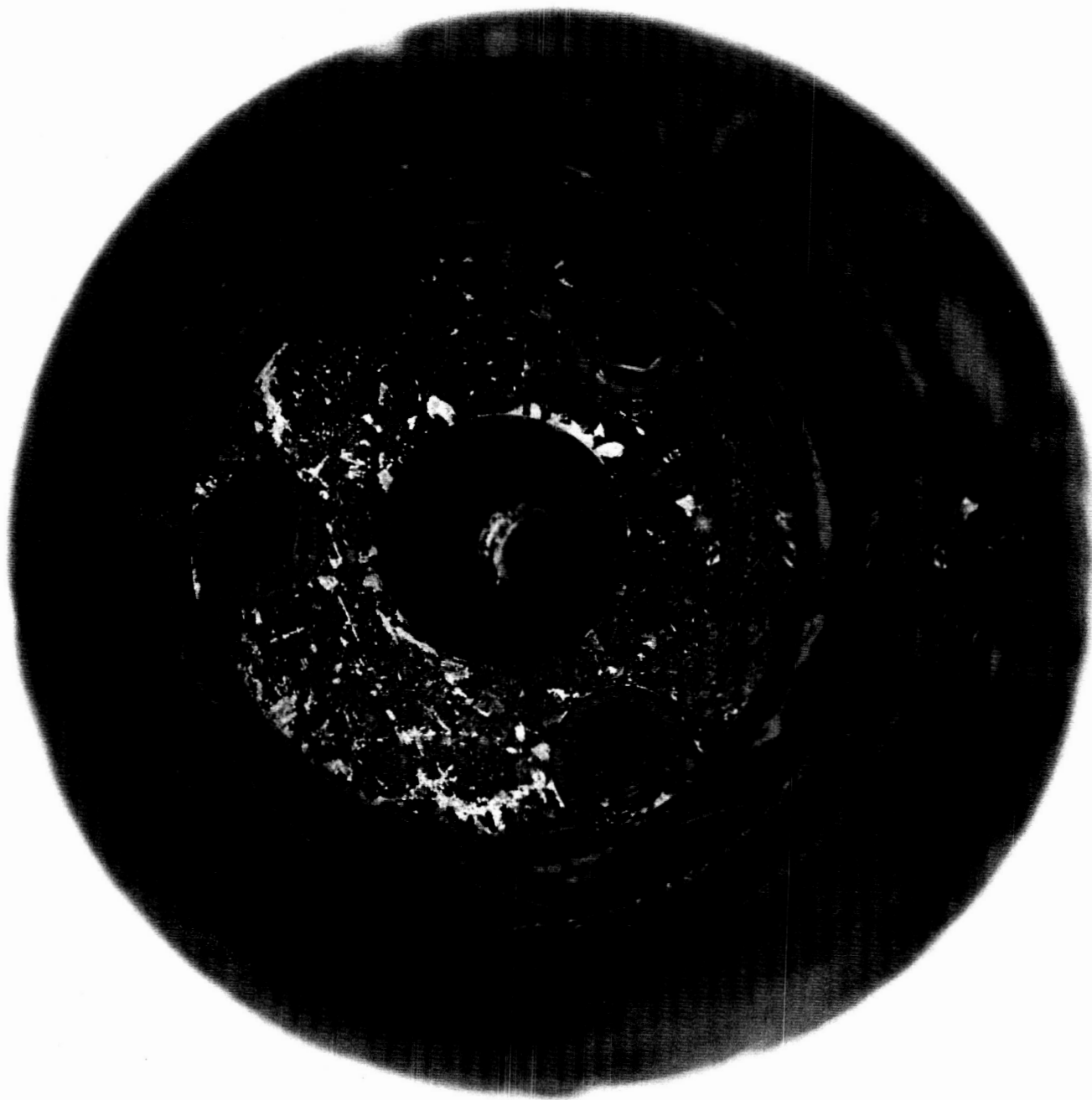
Two cracks appeared in the LH aft field joint closeout
where the trunnion had been potted in with K5NA



The trailing edge of the LH aft segment factory joint EPDM moisture seal showed debonds around the entire circumference



K5NA thermal protective domes were missing from bolt heads on the aft side of the kick ring. Uncovered substrate was sooted.



Three small pieces of shim material were wedged in the bore
against the HDP #4 debris plunger

126

ORIGINAL PAGE
COLOR PHOTOGRAPH



Broaching of the RH aft skirt HDP #3 stud hole and loss of
40% of the bonded shim during ascent due to stud hang-up

127

ORIGINAL PAGE
COLOR PHOTOGRAPH



Lab inspection of HDP #3 frangible nut shows tensile failure of the material and indicates non-simultaneous firing of ordnance

8.0 ORBITER POST LANDING DEBRIS ASSESSMENT

A detailed Post Landing Inspection of OV-103 (Discovery) was conducted November 27-28, 1989, at Ames-Dryden (EAFB) on Runway 04 and in the Mate/Demate Device (MDD) to identify debris impact damage, and if possible, debris sources. The Orbiter TPS sustained a total of 118 hits, of which 21 had a major dimension of one inch or greater. This total does not include the approximately 100 hits on the base heat shield.

The Orbiter lower surface had a total of 107 hits, of which 21 had a major dimension of one inch or greater. A heavy concentration of hits (28) occurred just aft and inboard of the LH2 umbilical. This concentration of hits has been observed previously and is attributed to umbilical ice impacts during ET separation. The remainder of the lower surface damage was approximately equally divided about the vehicle centerline. A comparison of these numbers to statistics from 18 previous missions of similar configuration (excluding missions STS-24, 25, 26, 26R, 27R, and 30 which had damage from known debris sources), indicates the total number of hits on the lower surface is average. Also, based on the severity of damage as indicated by surface area and depth, this flight is considered to be better than average. Figures 13-16 show the TPS debris damage assessment for STS-33R.

The single largest damage area occurred on the right side of the rudder/speed brake and involved two trailing edge tiles. These tiles were not damaged by debris impacts, but probably were the result of the combined launch environment (acoustics, heating, etc) during ascent.

Damage to the base heat shield tiles was less than average. The SSME engine mounted heat shield closeout blankets were damaged: 3 to 6 o'clock on SSME #1, 12 to 3 o'clock on SSME #2, and 9 to 10 o'clock on SSME #3. SSME nozzle insulation was not damaged. One Q-felt plug was missing from a closeout panel screw hole.

Several pieces of gap filler sleeving material were loose on the RH OMS pod. No visual damage to adjacent tiles resulted from these loose gap fillers.

White streaks were present on both wing leading edge RCC panels. There were 12 streaks on the left side and 7 on the right side. Orbiter window #3 was heavily hazed with 5 streaks. Window #4 was lightly hazed and window #5 had 6 streaks. Several pieces of tape or charred tape residue adhered to the surface of tiles. Samples of the deposits/material were taken from the windows, RCC wing panels, and other selected damage sites, as shown in Figures 17 and 18, for laboratory analysis.

The separation ordnance devices functioned properly. The debris plungers seated on EO-2 and EO-3. The EO-1 bipod yoke bolt piston was flush with the outer mold line. More detailed

STS-33R

FIGURE 13. DEBRIS DAMAGE LOCATION

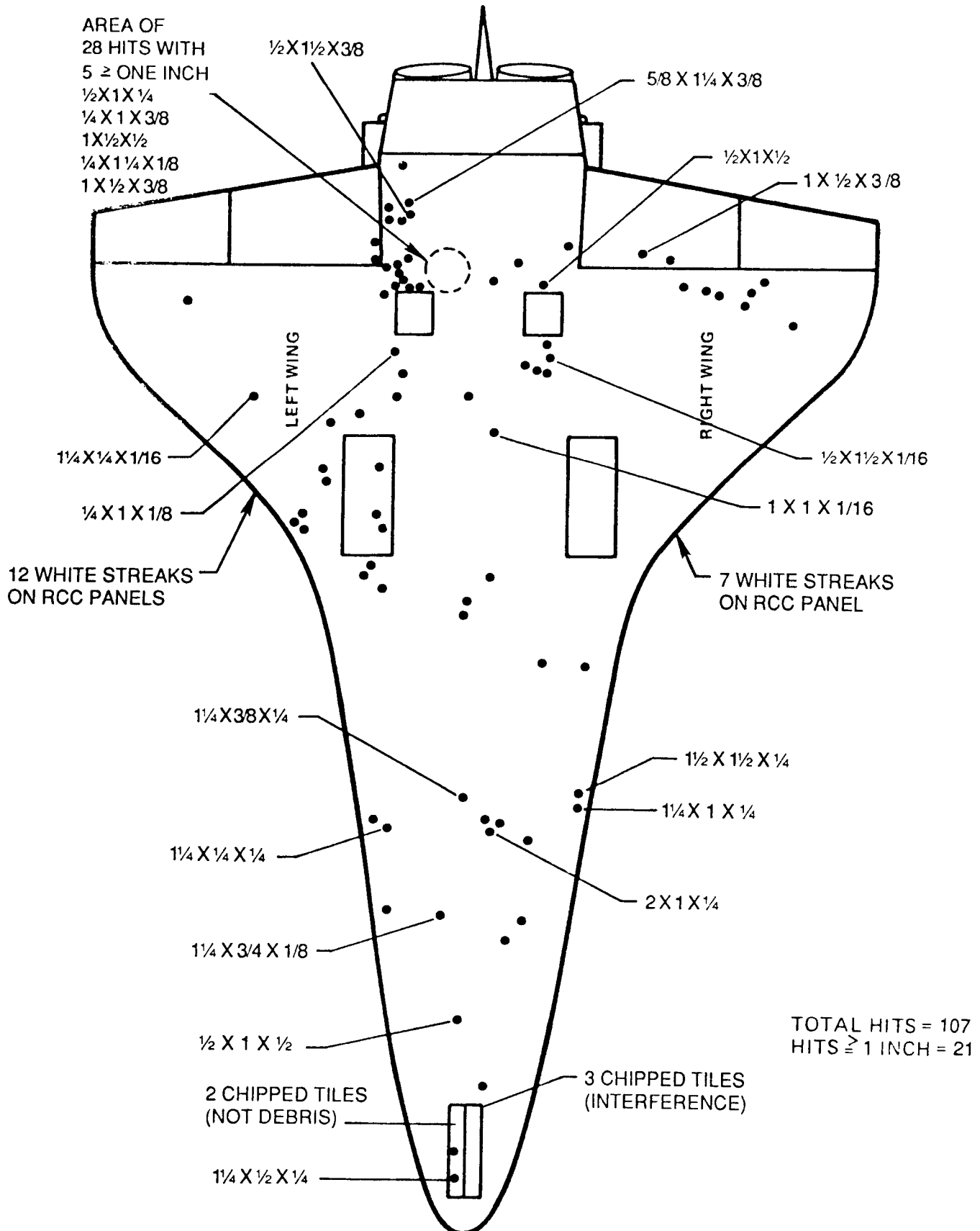


FIGURE 14. **DEBRIS DAMAGE LOCATION**

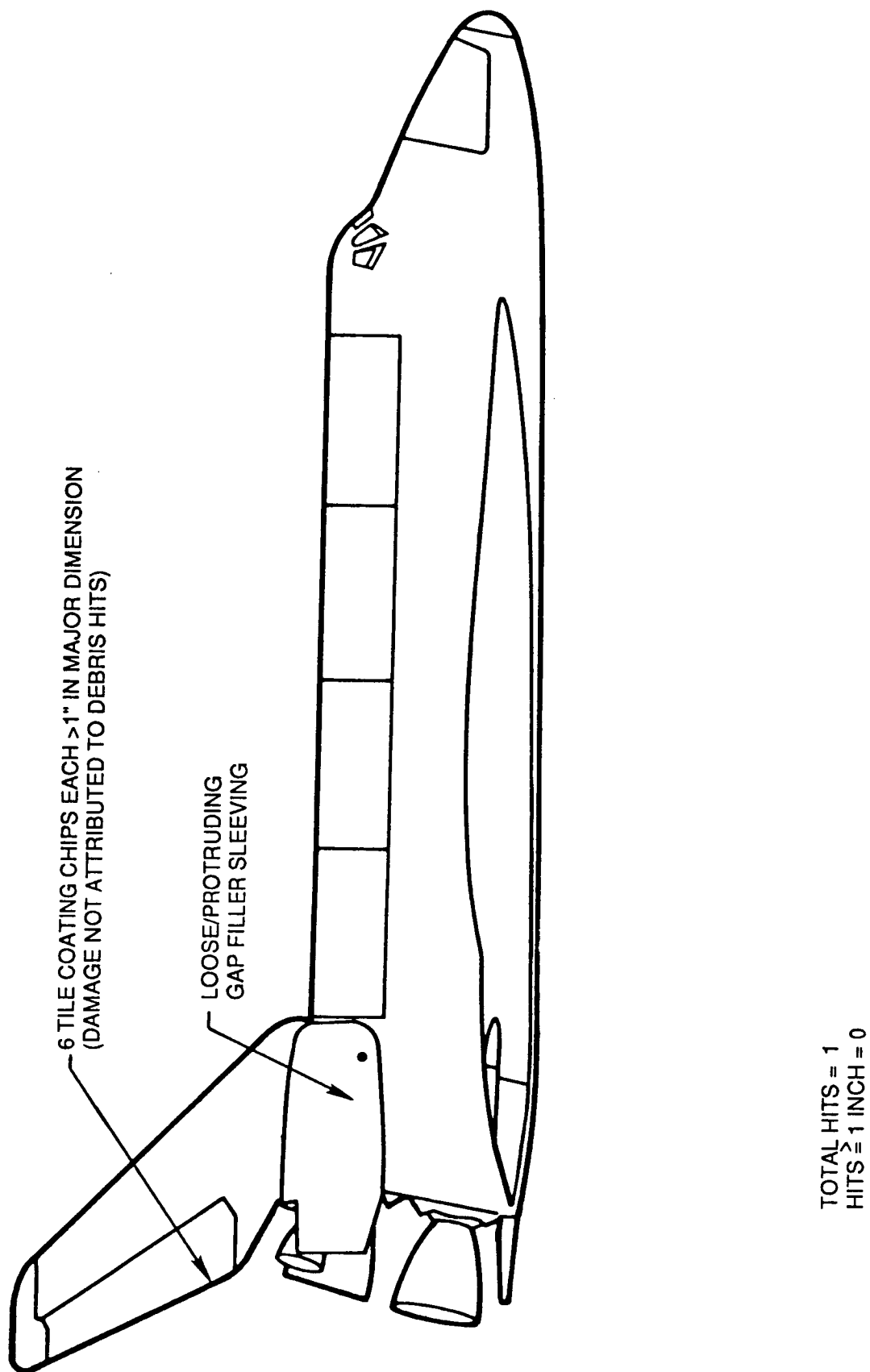
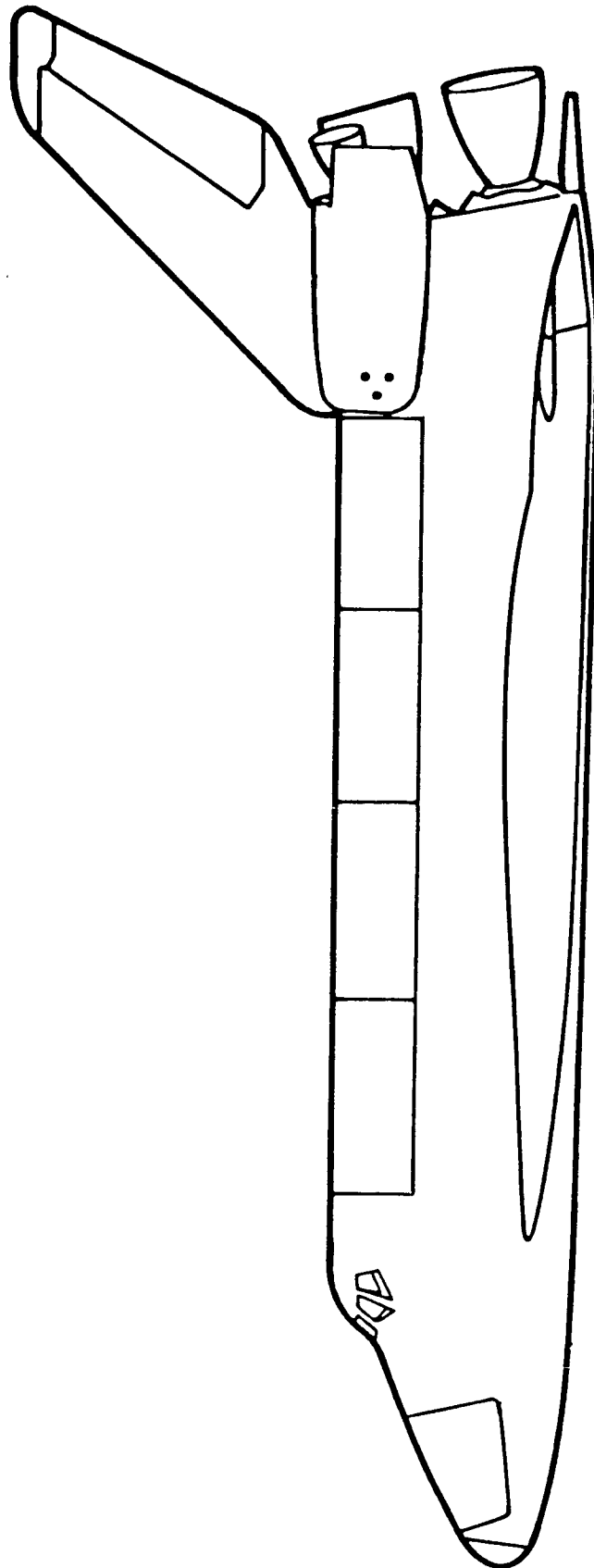


FIGURE 15. DEBRIS DAMAGE LOCATION



TOTAL HITS = 3
HITS \geq 1 INCH = 0

FIGURE 16. **DEBRIS DAMAGE LOCATION**

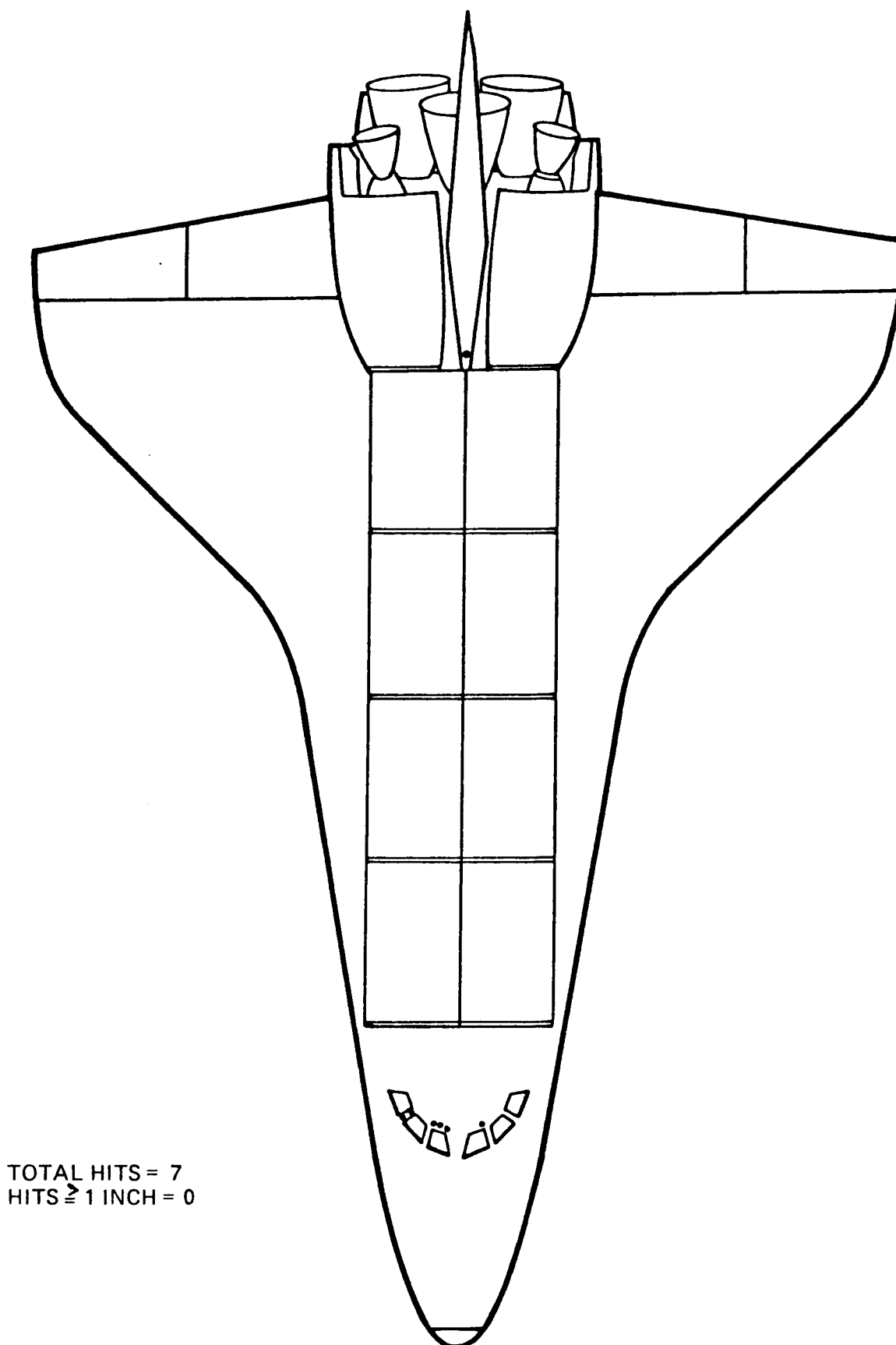


FIGURE 17. **DEBRIS DAMAGE CHEMICAL SAMPLE LOCATIONS**

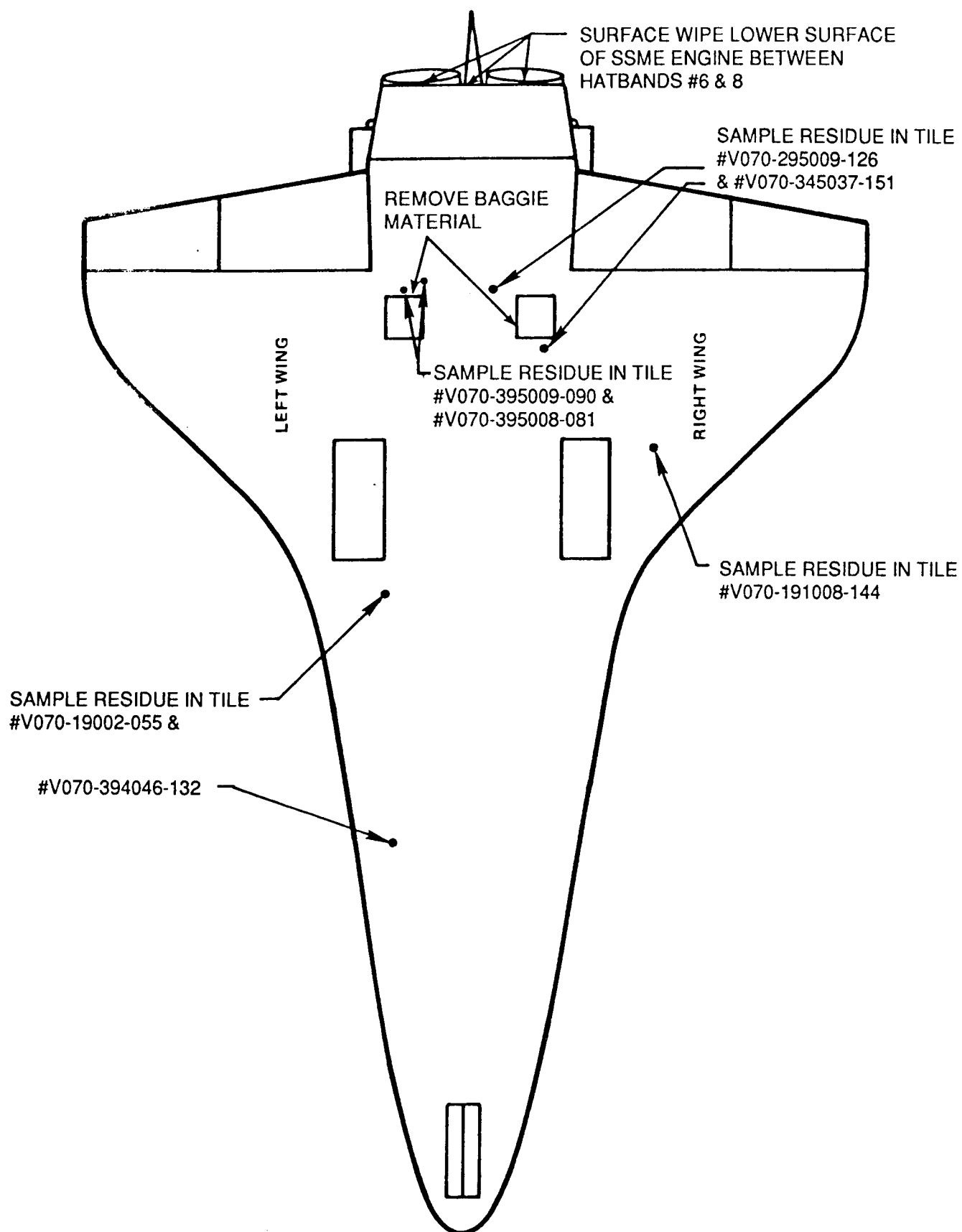
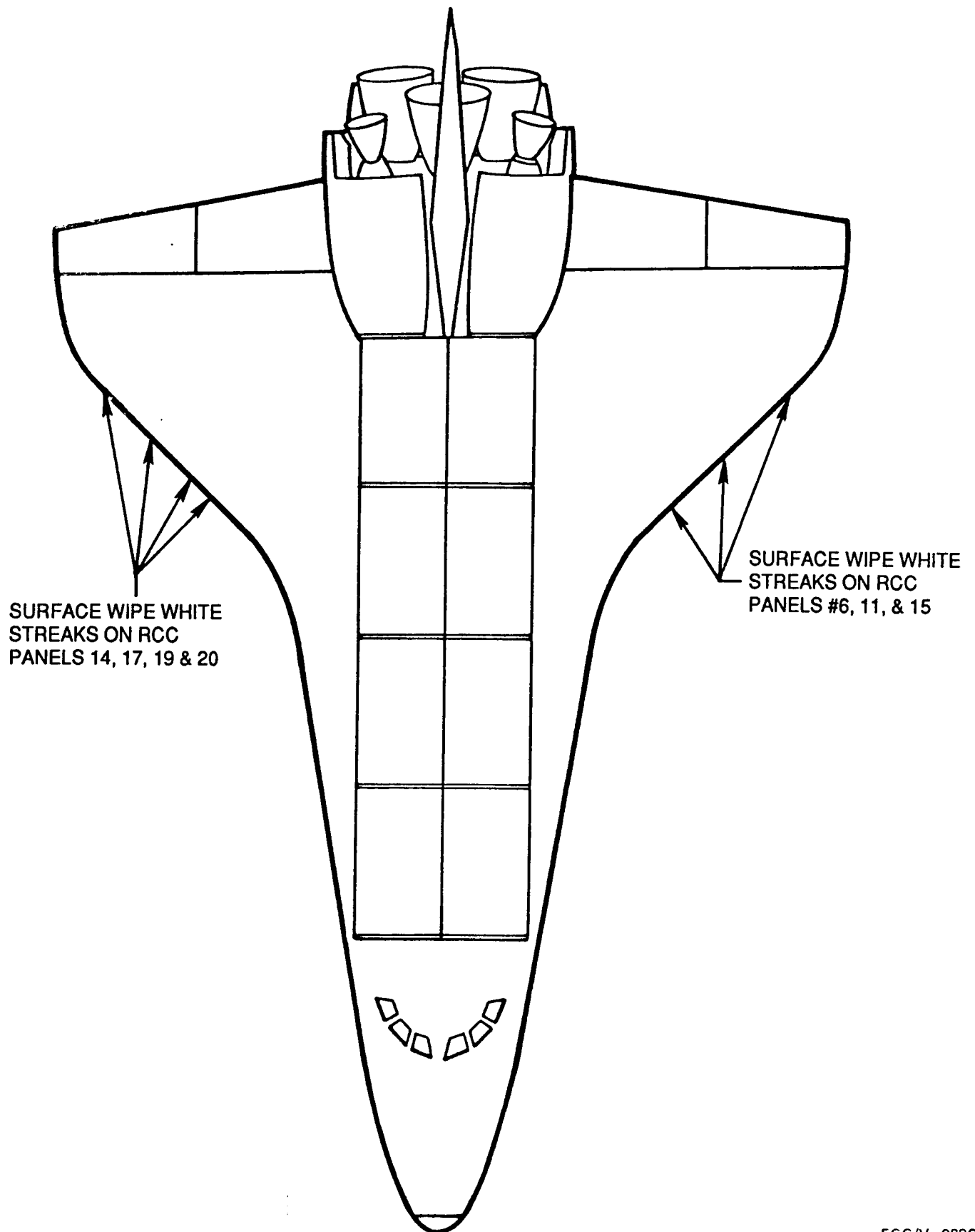


FIGURE 18. **DEBRIS DAMAGE CHEMICAL SAMPLE LOCATIONS**



inspection of EO-1 revealed the ordnance device had rotated forward sufficiently to contact and break the LH bulkhead pyrotechnic connector backshell. There is also evidence of this contact on the ordnance device LH spring housing. The Y-Y centering bolt, which had bent on STS-34, was not damaged during this flight.

No TPS damage was attributed to material from the tires, wheels, and brakes.

The KSC Shuttle Thermal Imager (STI) was used to record the kinetic surface temperatures of several areas to establish a post landing thermal data base. The nose cap RCC measured 150 degrees F eleven minutes after landing. Seventy minutes after landing, the wing RCC panels measured 58 degrees F. The infrared data is shown in Figure 19.

Runways 17L and 23L/05R were inspected by the Debris Team on November 26 and 27, 1989, and potentially damaging debris was removed. The general condition of the runways was good. Runway 22/04 was cleaned and inspected by Air Force personnel.

The post landing walkdown of Runway 04 was initiated at approximately Landing + 1/2 hour. No flight hardware was found.

In summary, the total number of lower surface Orbiter TPS debris hits was average when compared to previous flights, as shown in the comparison charts (Figure 20, 21). The distribution of hits on the Orbiter does not point to a single source for ascent debris, but indicates a shedding of ice and TPS debris from random sources. The potential identification of debris sources for mission STS-33R will be based on the laboratory analysis of TPS damage sites, inspection of the recovered SRB components, and photographic analysis.

Orbiter Post Launch Anomalies are listed in Section 10.4.

FIGURE 19. TEMPERATURE MEASUREMENTS

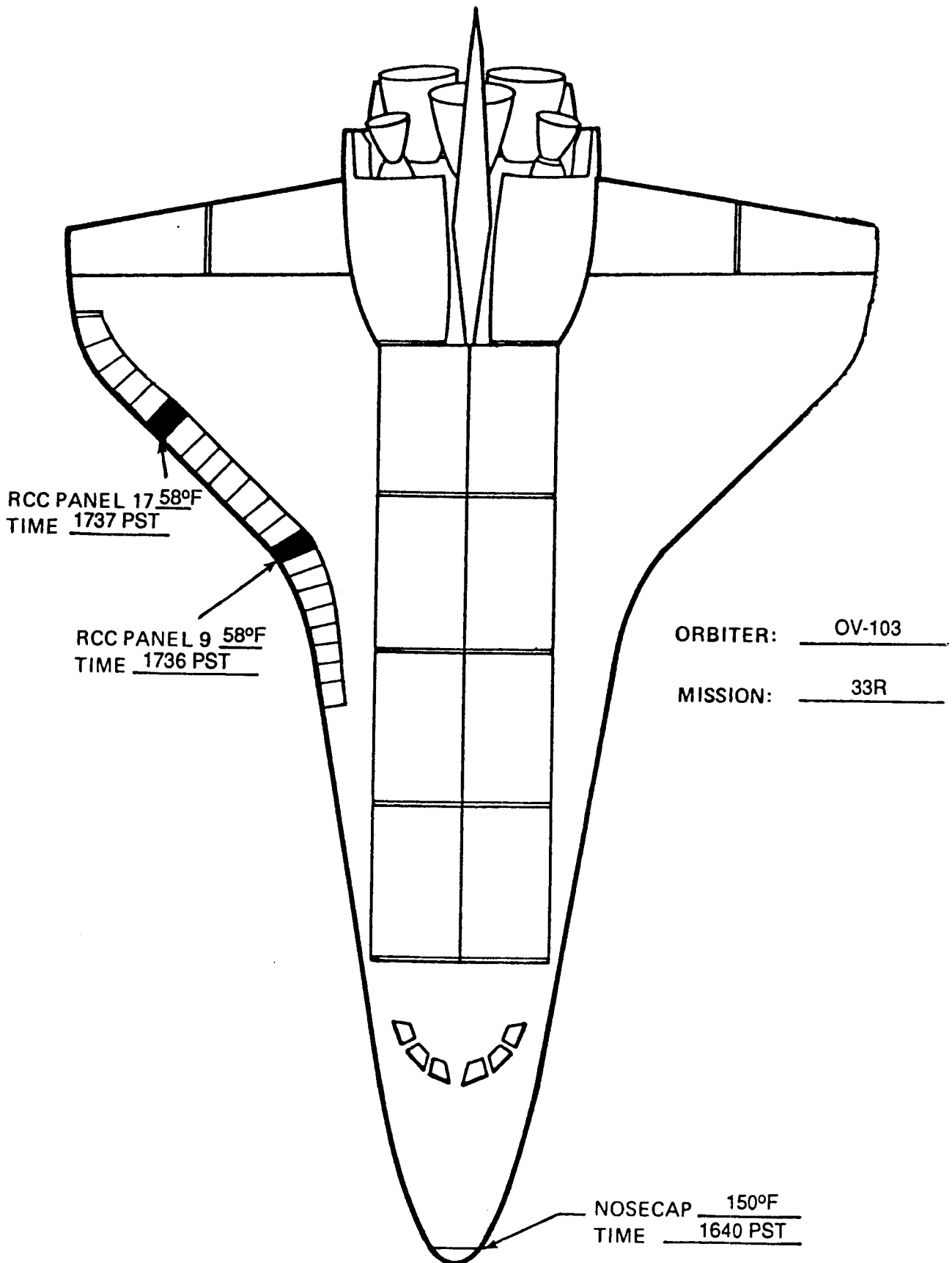


FIGURE 20. STS-33R DEBRIS DAMAGE ASSESSMENT SUMMARY

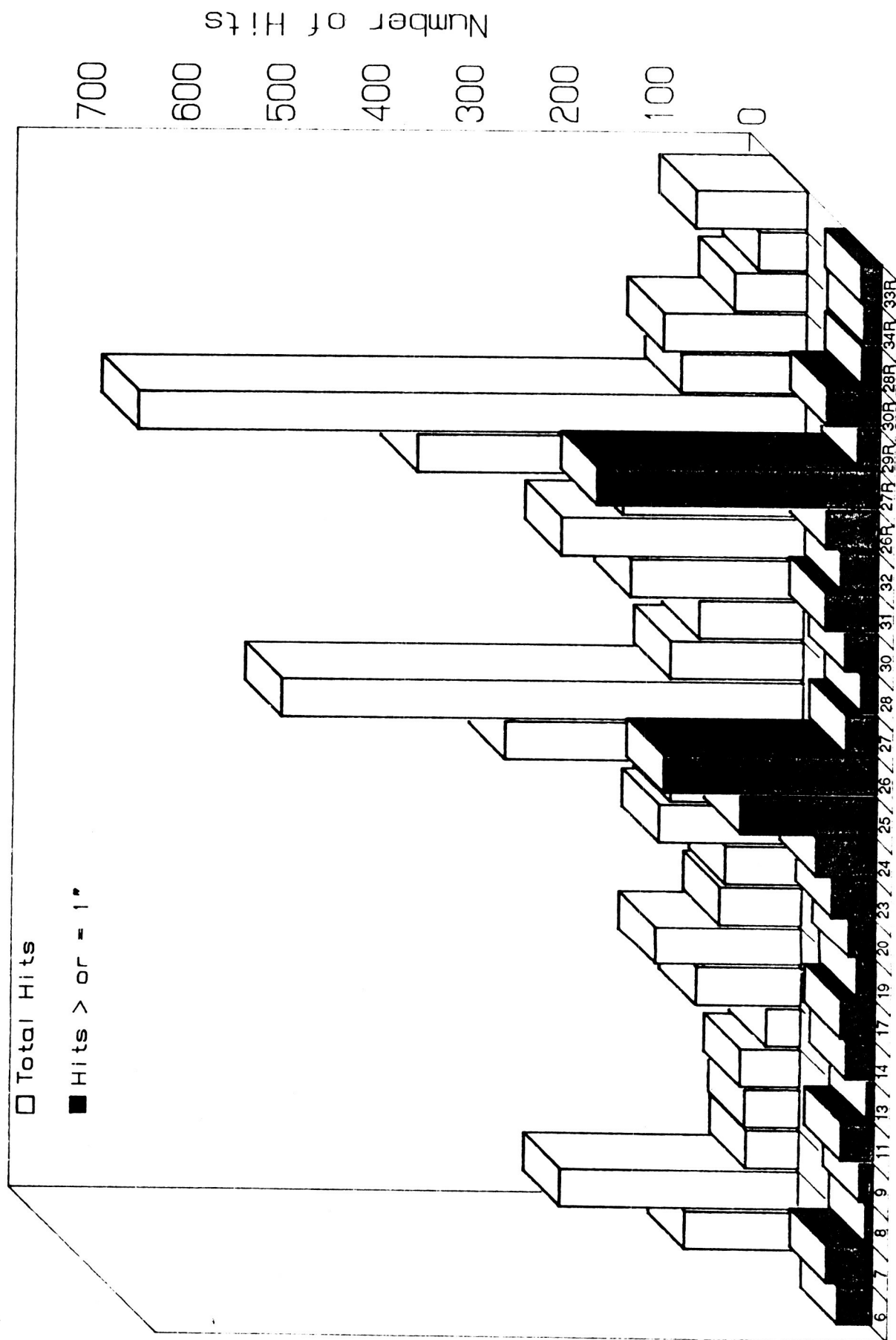
	<u>Hits > or = 1"</u>	<u>Total Hits</u>
Lower Surface	21	107
Upper Surface	0	7
Right Side	0	0
Left Side	0	0
Right OMS Pod	0	1
Left OMS Pod	0	3
TOTALS	21	118

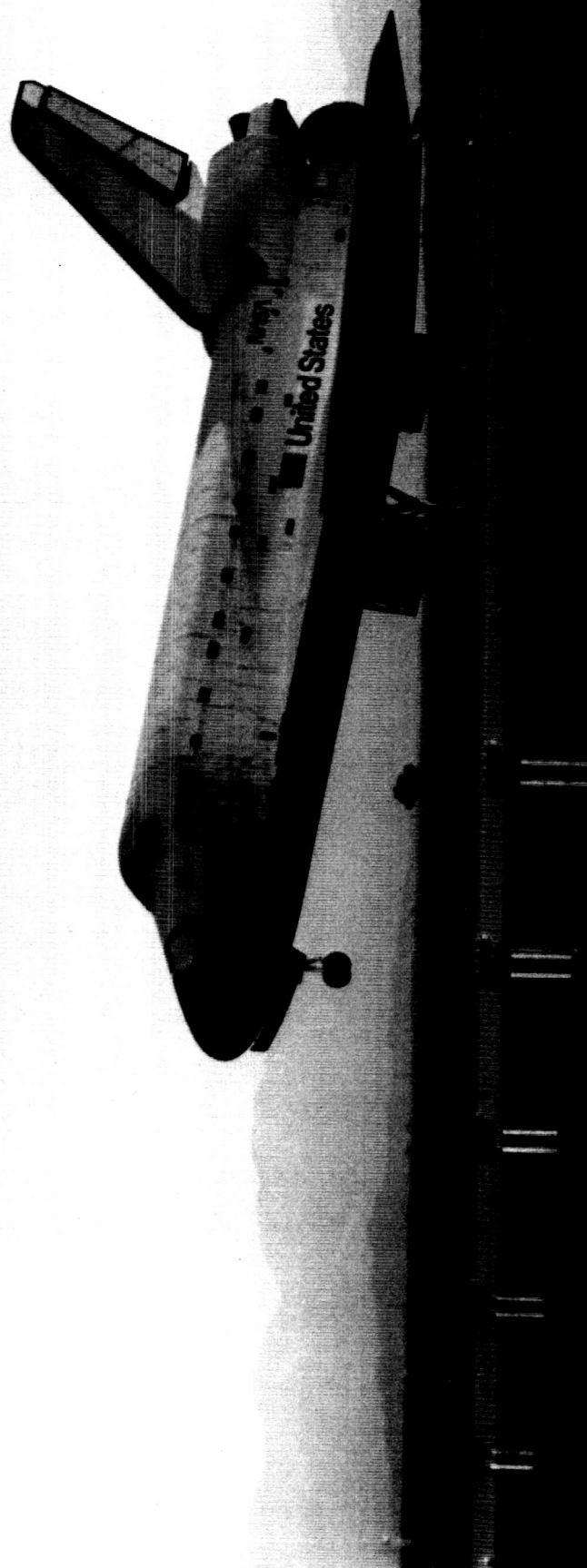
COMPARISON TABLE

STS-6	36	120
STS-7	48	253
STS-8	7	56
STS-9 (41-A)	14	58
STS-11 (41-B)	34	63
STS-13 (41-C)	8	36
STS-14 (41-D)	30	111
STS-17 (41-G)	36	154
STS-19 (51-A)	20	87
STS-20 (51-C)	28	81
STS-23 (51-D)	46	152
STS-24 (51-B)	63	140
STS-25 (51-G)	144	315
STS-26 (51-F)	226	553
STS-27 (51-I)	33	141
STS-28 (51-J)	17	111
STS-30 (61-A)	34	183
STS-31 (61-B)	55	257
STS-32 (61-C)	39	193
STS-26R	55	411
STS-27R	298	707
STS-29R	23	132
STS-30R	56	151
STS-28R	20	76
STS-34	18	53
STS-33R	21	118

COMPARISON TABLE

FIGURE 21.

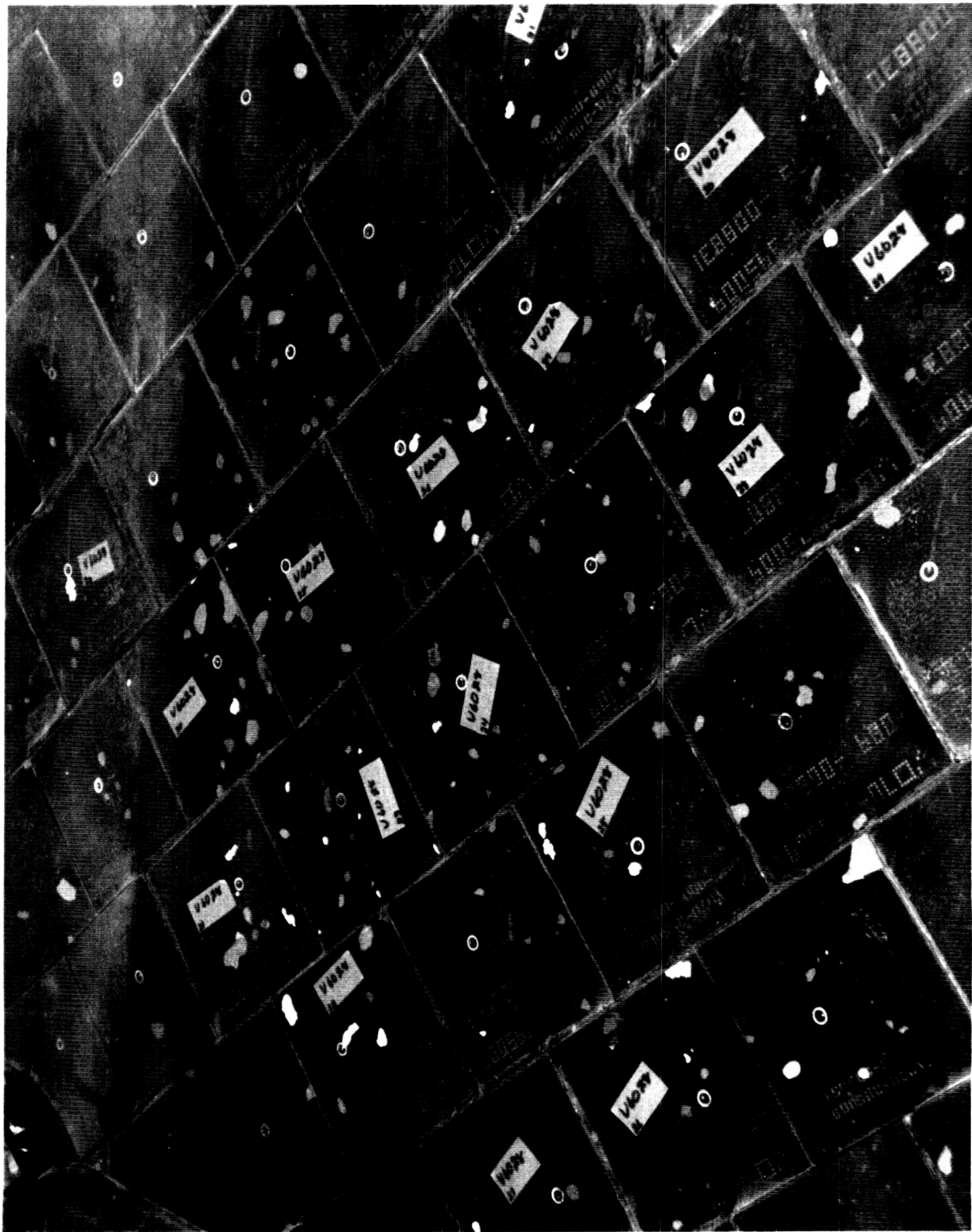




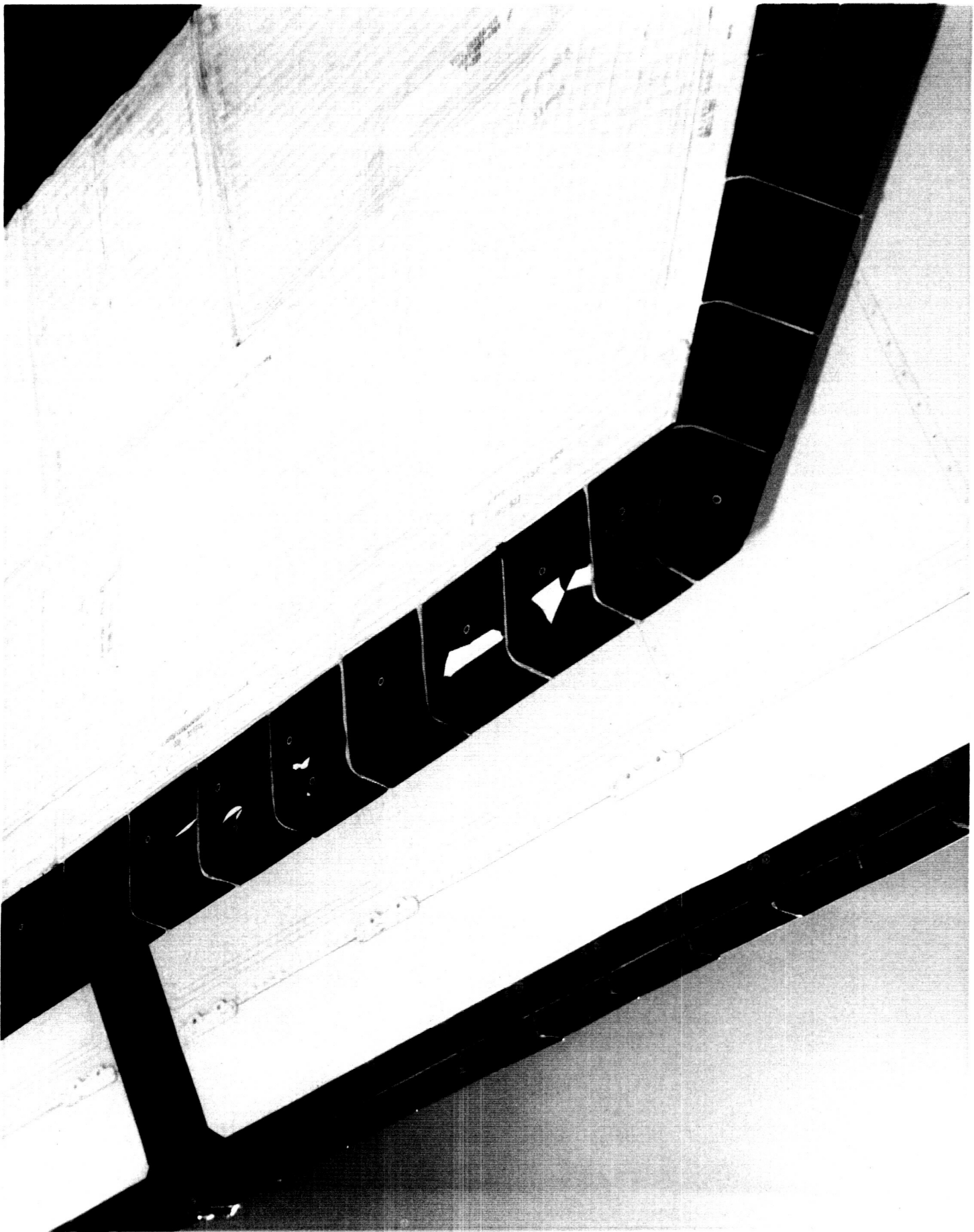
Discovery landing at Ames-DFRF on Runway 04



Overall view of Orbiter right side after landing



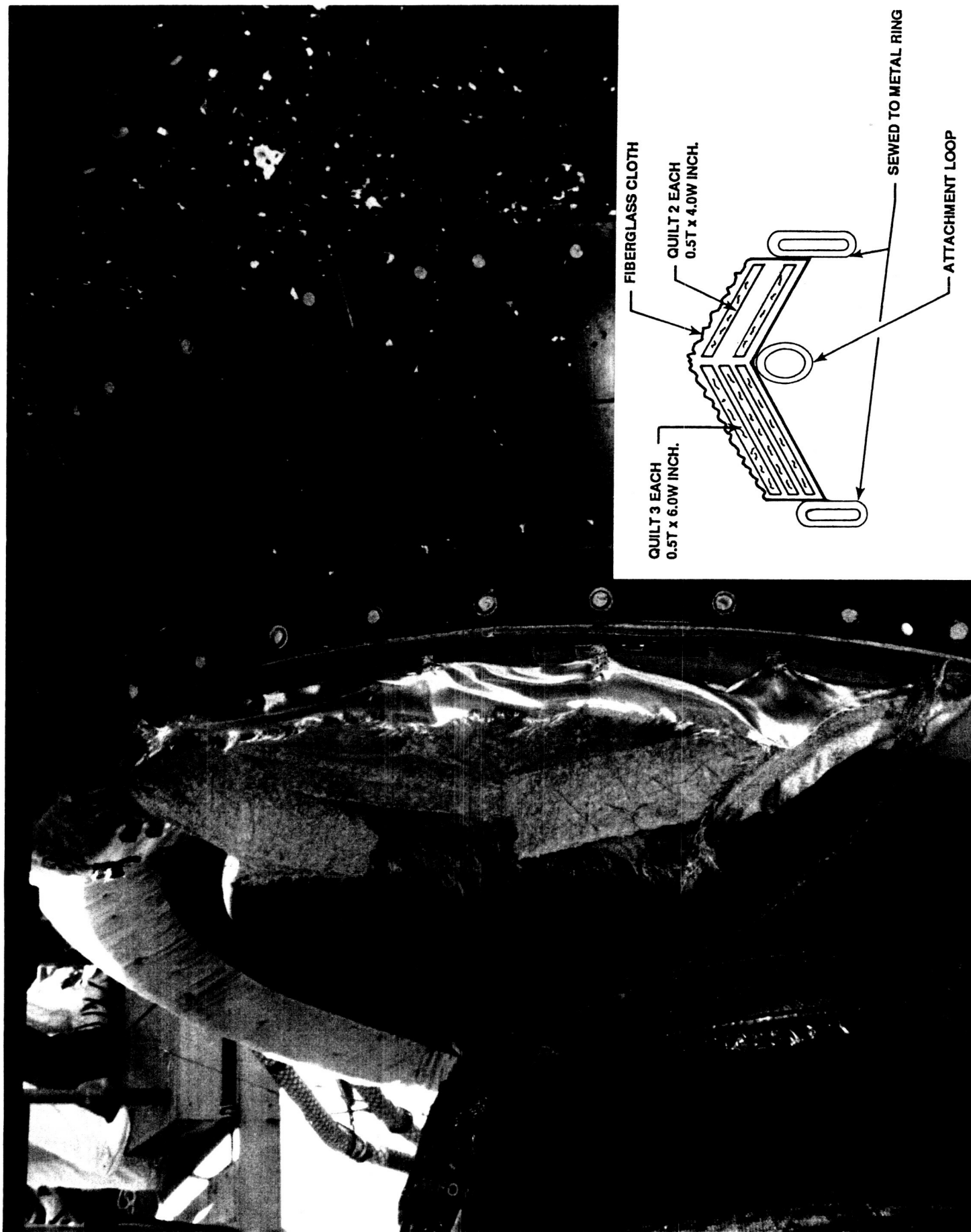
A concentration of 28 hits occurred aft and inboard of the
LH2 umbilical and was attributed to umbilical ice impacts



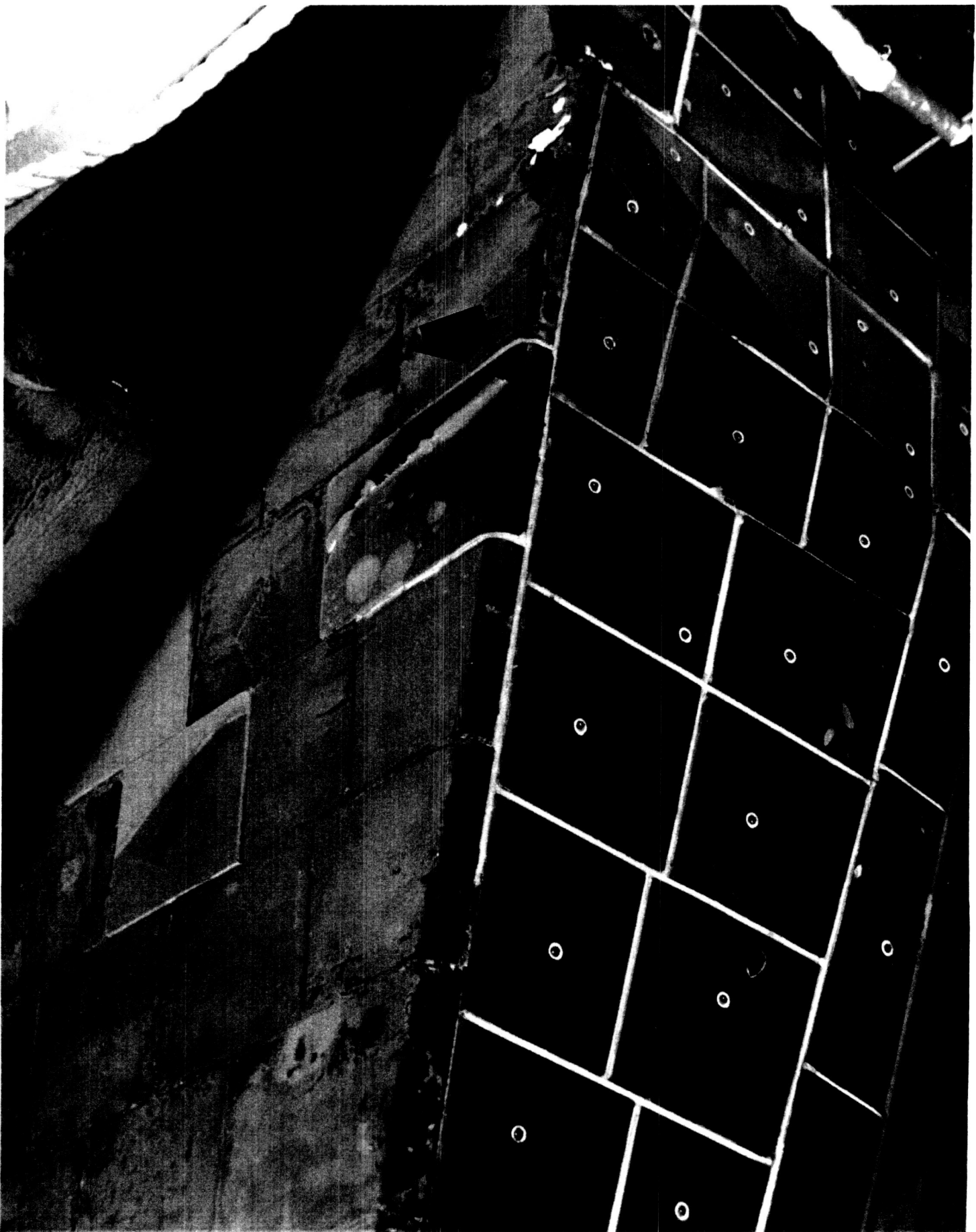
Damage to the trailing edge tiles on the rudder/speed brake
right side was caused by acoustics during ascent



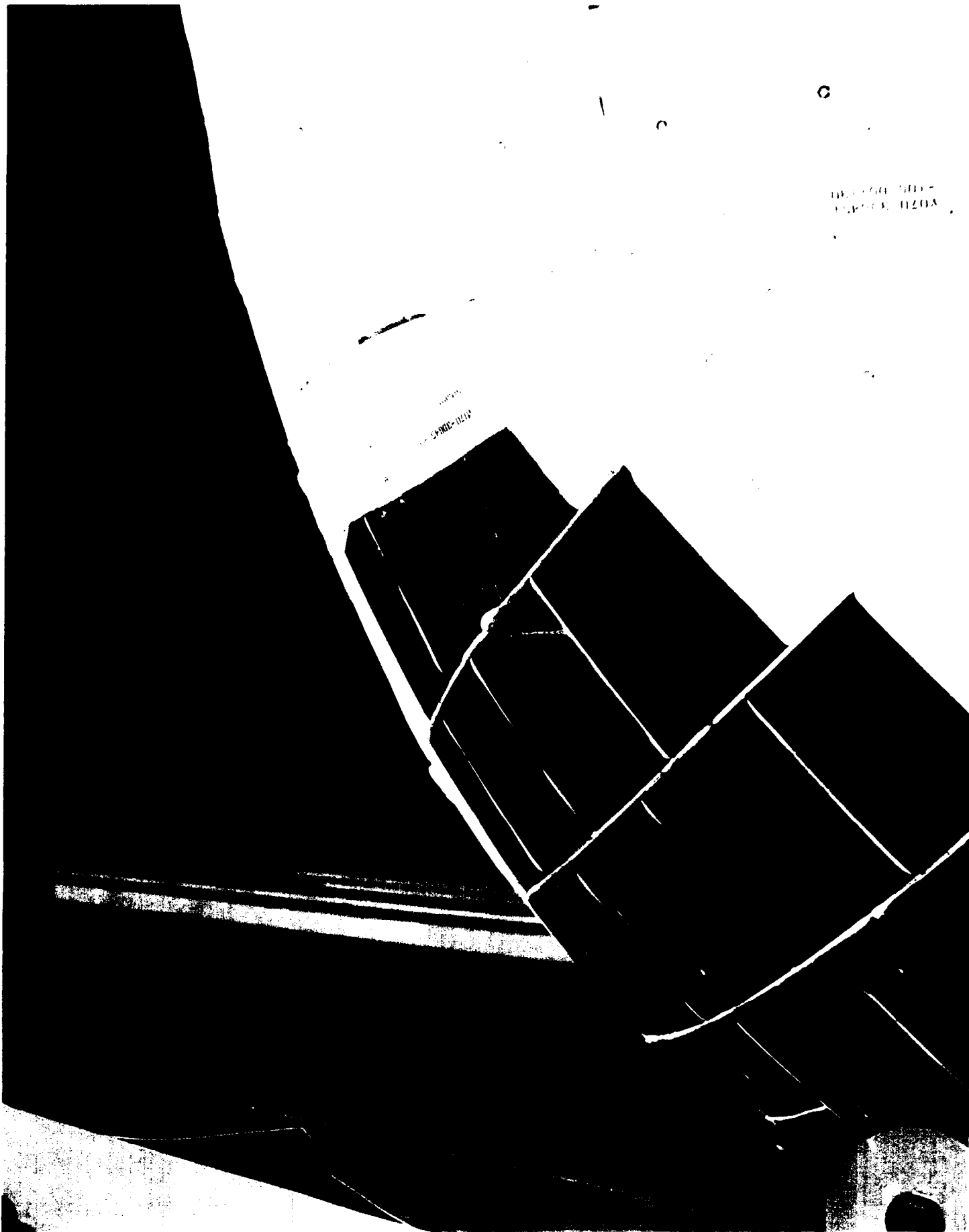
SSME ignition acoustics and vibration caused tile surface
coating material to fall from the base heatshield near SSME #3



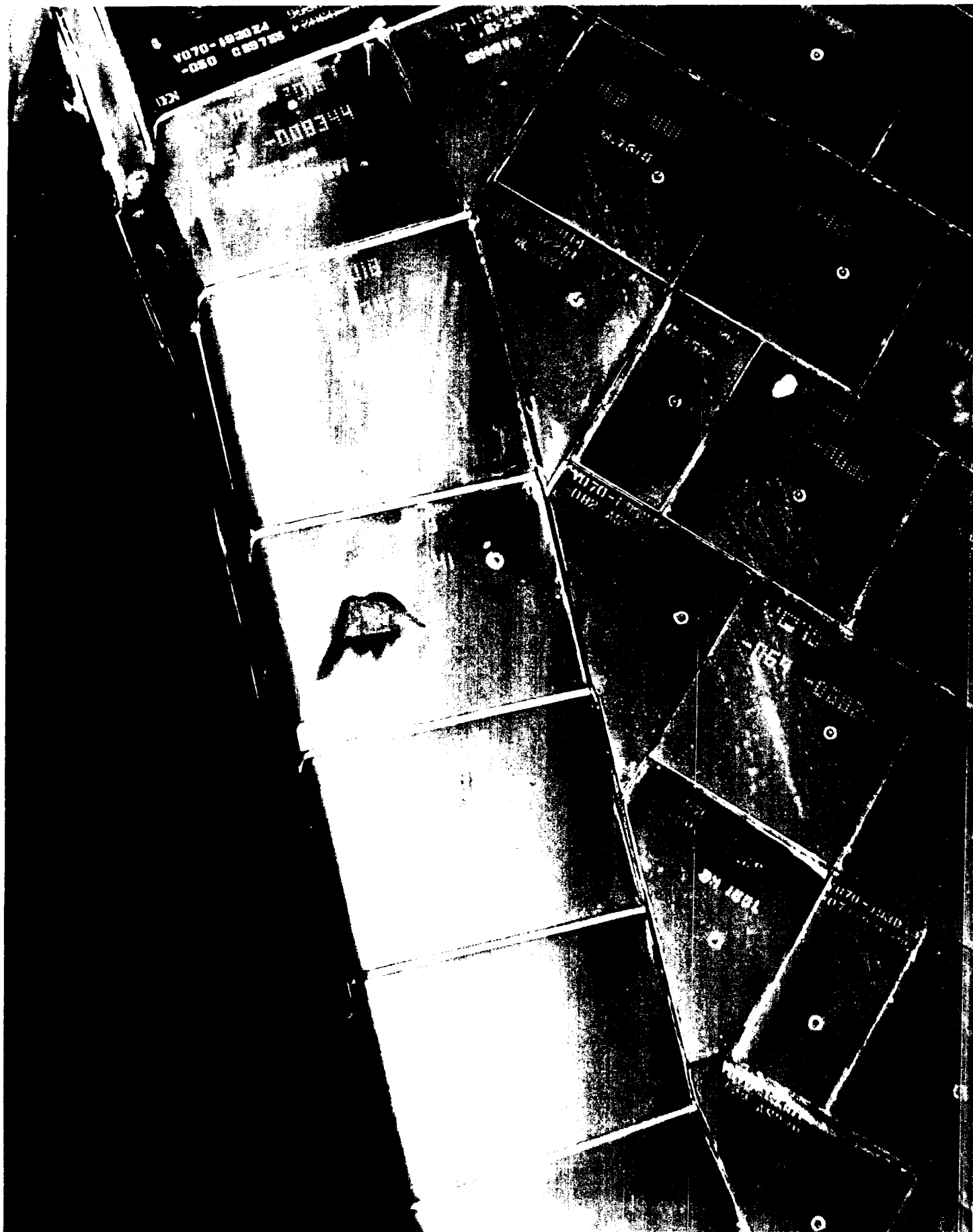
SSME engine-mounted heat shield closeout blankets
were torn and frayed



New (test) tile surface coating material on the body flap used
to protect tiles from RCS plume impingement was debonded



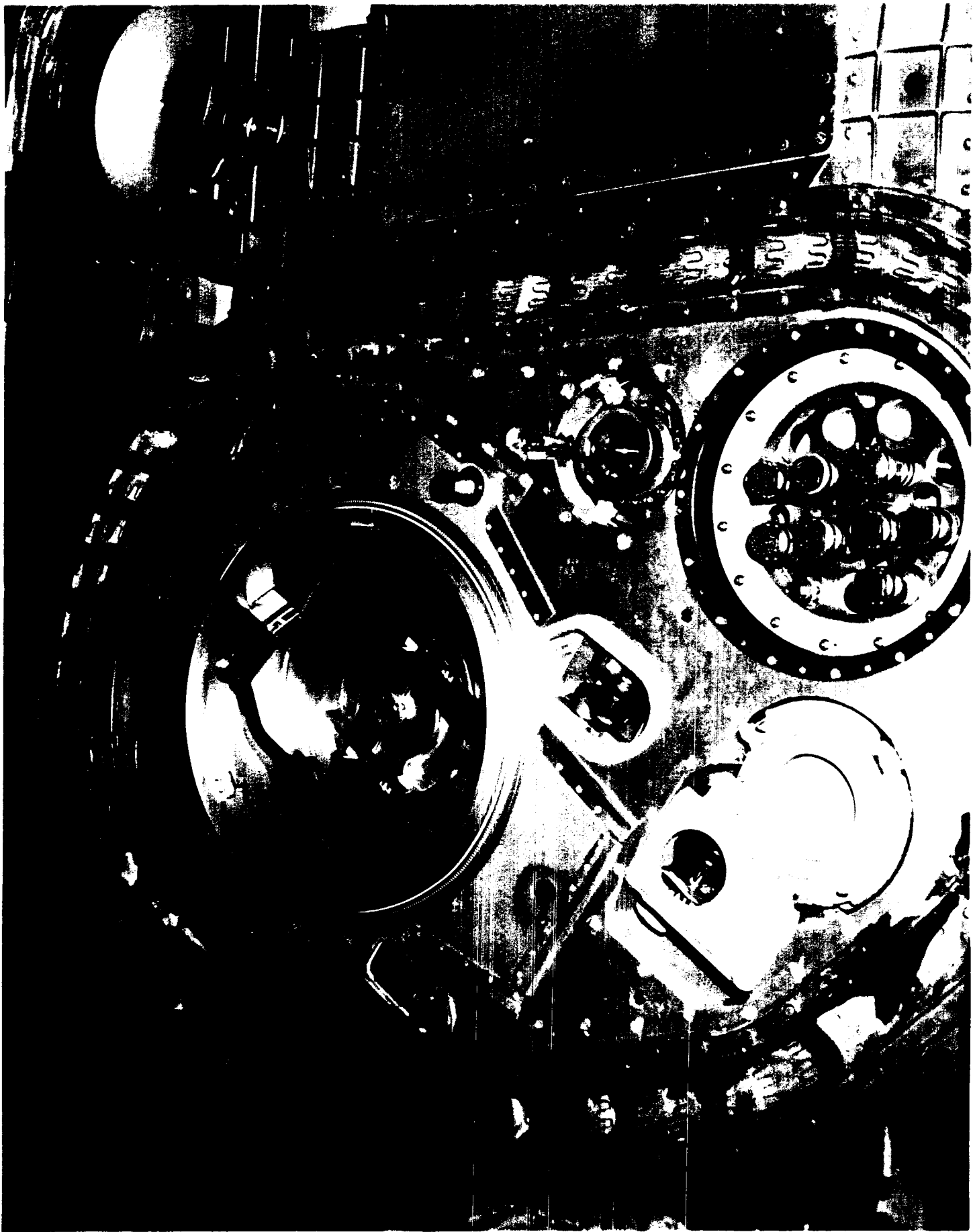
Several pieces of gap filler sleeving material were loose
on the RH OMS pod



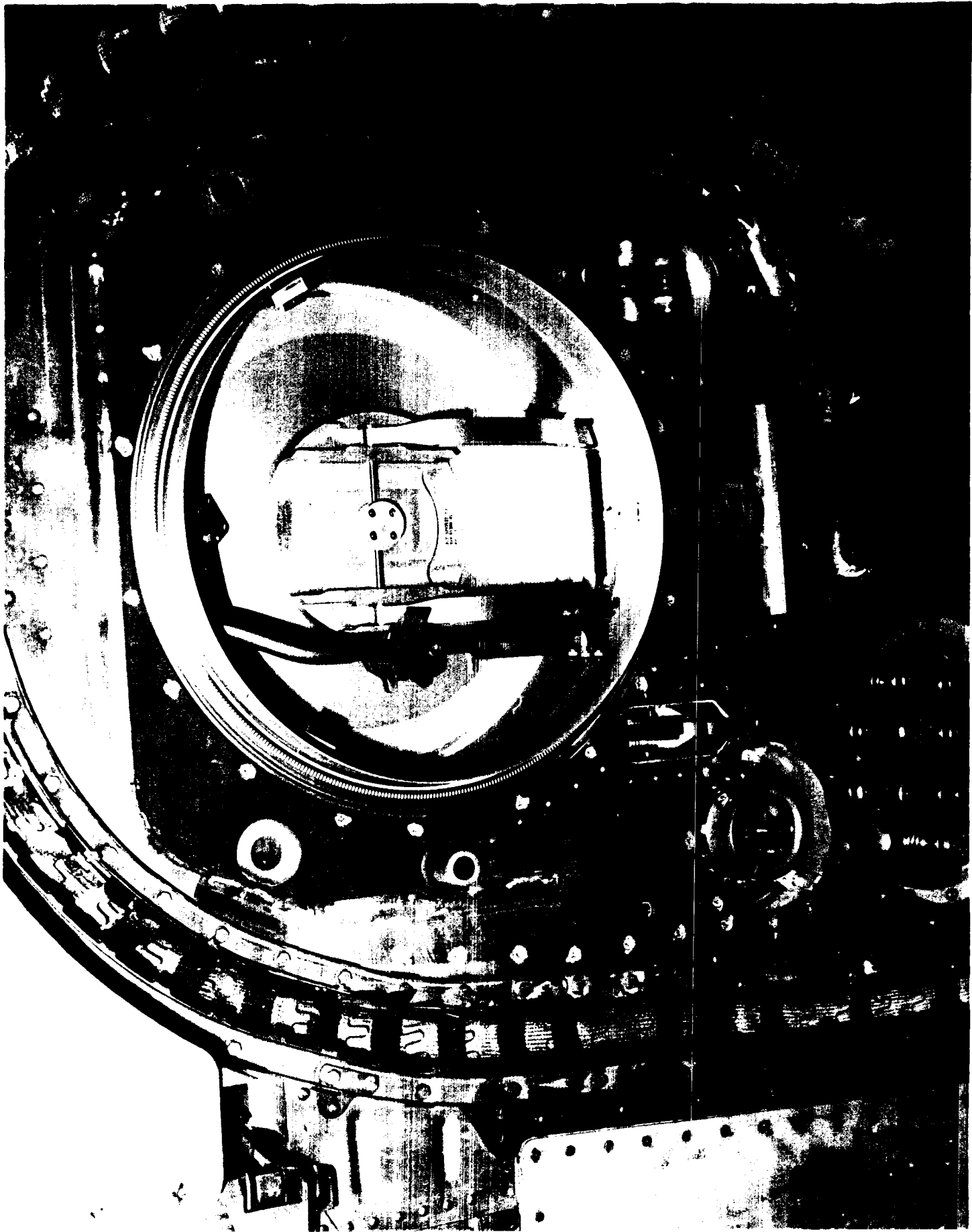
A piece of tape or charred tape residue adhered to the
surface of a tile



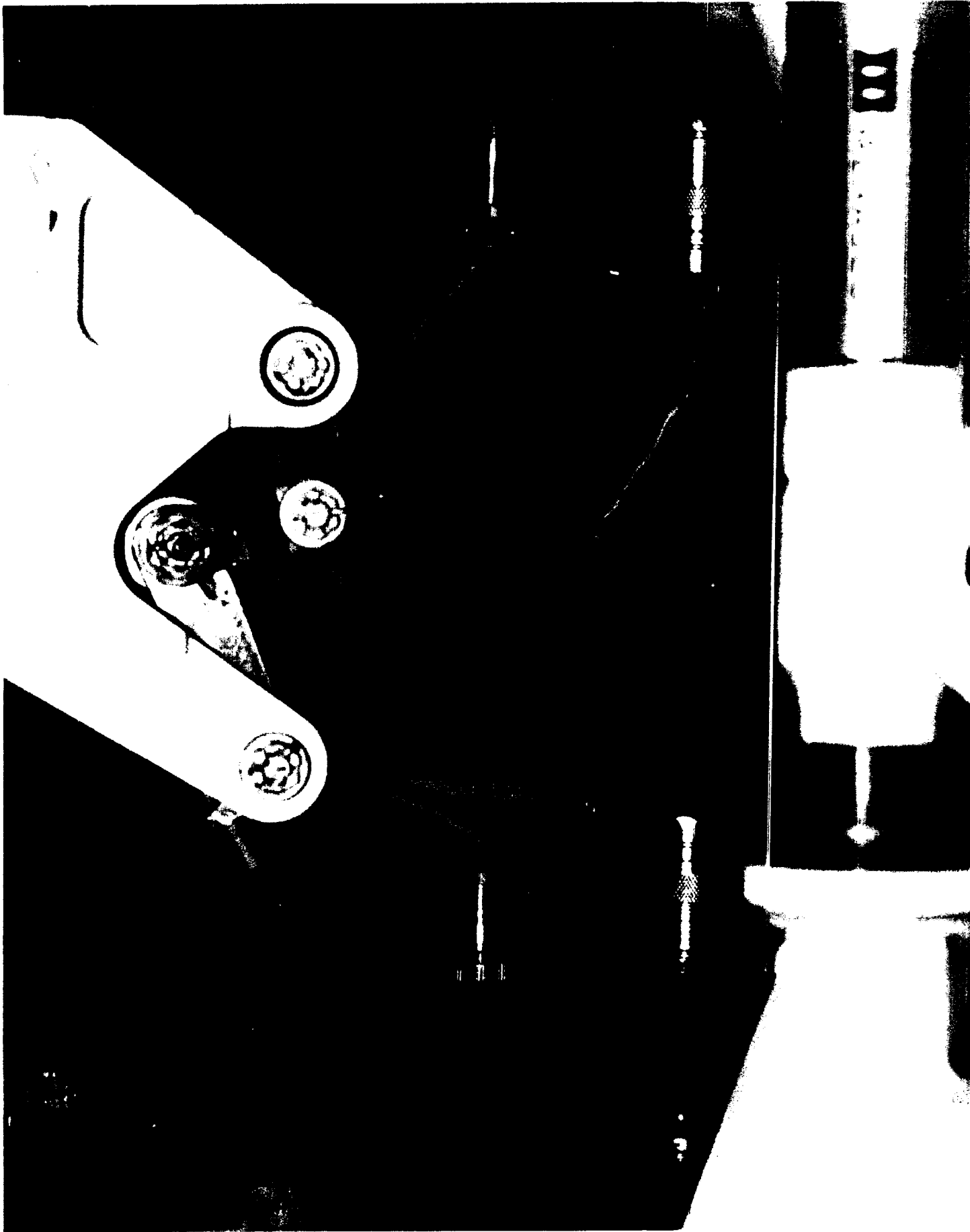
Damage to a previous tile repair



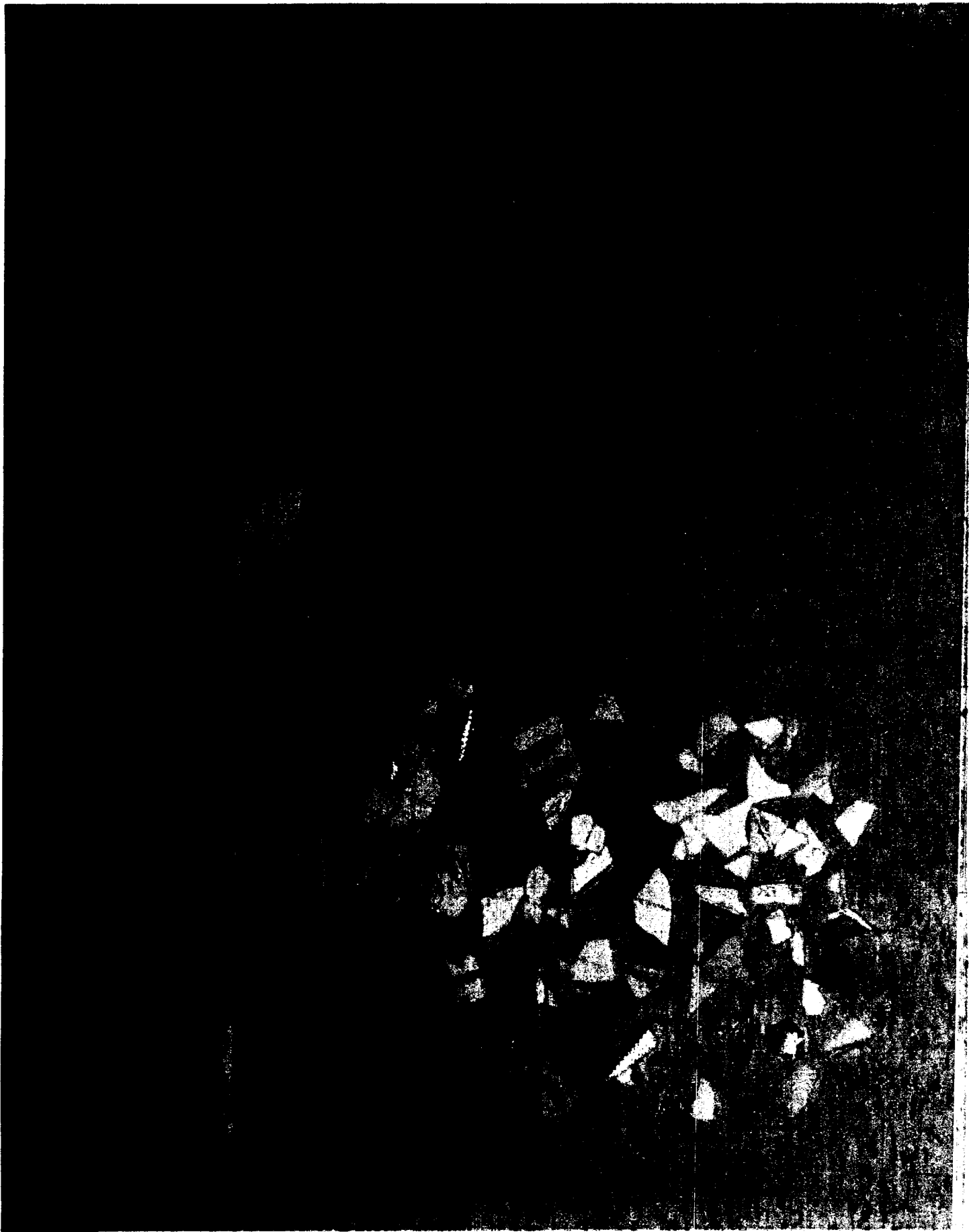
Overall view of ET/ORB LH2 umbilical. Note closeout foam intrusion on the purge barrier sealing surface.



Overall view of ET/ORB LO2 umbilical



Inspection of EO-1 revealed a broken LH bulkhead pyrotechnic connector backshell. Note difference from opposite side.



Typical debris collected during the Pre-landing Runway
Inspection

9.0 DEBRIS SAMPLE LAB REPORTS

POST-LAUNCH PAD DEBRIS

Samples recovered during STS-33R post-launch inspection were submitted to the NASA Microchemical Analysis Branch (MAB) for identification testing. The laboratory identified two chemical compounds of similar composition - siliceous (silicon) filled epoxy resins (one a polyvinyl acetate-phthalate ester). The source of these compounds is still under investigation, but is most likely a facility area requiring a durable and temperature sensitive (due to silica presence) material protection. These type of materials were also found during STS-30R and STS-28R post-launch inspections.

ORBITER DEBRIS

A total of 26 samples were obtained from the STS-33R Orbiter during post-landing debris assessment operations at Ames-Dryden Flight Research Facility, California. The 26 submitted samples (ref Figures 17 and 18 for locations) consisted of 8 Orbiter window wipes (W-1 thru W-8), 7 tile samples, 7 wing RCC samples, 2 SSME nozzle samples, 1 ET/ORB umbilical sample, and 1 wipe from Orbiter crew hatch window (W-11). All samples were analyzed by the NASA-KSC Microchemical Analysis Branch (MAB) for material composition and comparison to known STS materials. The specific elemental analysis is shown in the appended Microchemical Analysis Branch reports. Debris sample analyses are provided by Orbiter location in the following summaries. An overall summary for the mission is provided as a conclusion.

ORBITER WINDOW WIPES

Results of window wipe chemical analysis indicates the presence of the following materials:

1. cadmium and copper metal
2. rust, dust and salt
3. red paint
4. light brown flakes
5. light gray powder
6. glass fiber
7. orange-red materials

Debris analysis provides the following correlations:

1. Cadmium and copper metals are common to the landing site, and are not a debris concern in this quantity (micrometer).
2. Rust is probably an SRB BSM residue; dust and salt are probable landing site products.
3. Red paint is used on markings for the Orbiter.

4. Light brown flakes were identified as muscovite, a naturally-occurring landing site product.

5. Light gray powder was identified as amorphous silicon-aluminum, a product of thermal tile on re-entry. Cerium, an Orbiter window cleaning material base, and lanthanum, a natural landing site product, were also noted.

6. Glass fiber appears to be from Orbiter thermal protection system (TPS).

7. Orange-red materials that were rich in cerium, are probably an Orbiter cleaning compound residue.

ORBITER TILE

One of the seven tile samples did not provide sufficient material for analysis. The other six samples contained only tile thermal protection system materials. The absence of non-tile material indicates the damage-causing debris was not held at the damage site or the debris itself was tile materials.

ORBITER WING RCC PANELS

One of seven RCC samples did not provide sufficient material for analysis. Results of the analysis indicated the presence of the following materials:

1. Nickel and aluminum metal
2. Rust and dust
3. Muscovite
4. Paint
5. Salts and feldspar
6. Alpha-quartz (silica)
7. Insulation glass
8. Organics

Debris analysis provides the following correlations:

1. Nickel and aluminum metals are common to processing activities and could originate from the flight elements, facility, or ground support equipment. These particles are not associated with a damage site, indicating the residue size does not represent a debris concern.

2. Rust is probably of SRB BSM residue origin, dust is of naturally-occurring environmental origin.

3. Muscovite is a natural landing site product.

4. Paint particles may have originated from processing activities on the flight elements, facility, or ground support equipment.

5. Salts and feldspar are natural landing site products.

6. Alpha-quartz (silica) is one of the purest forms of the earth mineral and tile material base.

7. Insulation glass is a component of the Orbiter thermal protection system (TPS).

8. Organics could be linked to animal or insect remains and deposits.

SSME NOZZLE

Neither of the two SSME nozzle samples contained sufficient material for chemical composition analysis.

ET-ORBITER UMBILICAL (RH-LOX)

Chemical analysis of sample from the RH ET/ORBITER umbilical (LOX) revealed the following materials:

1. Rust and dust
2. Paint
3. RTV
4. Insulation glass
5. Polyurethane foam
6. Microballoon
7. Organics

Debris analysis of these materials provides the following correlations:

1. Rust is probably of SRB BSM residue origin, dust is of naturally-occurring environmental origin.
2. Paint may have originated from processing activities on the flight elements, facility, or ground support equipment.
3. RTV is used as a bond/sealant on the flight elements.
4. Insulation glass is a component of Orbiter thermal protection system.
5. Polyurethane foam is a closeout material for the umbilical.
6. Microballoon is a component of ET/SRB ablators.
7. Organics may be animal or insect remains and deposits.

ORBITER CREW HATCH WINDOW (W-11)

Chemical analysis of sample from the crew hatch window revealed the following materials:

1. Rust and dust
2. Paint
3. Alpha-quartz (silica)
4. Organics

Debris analysis provides the following correlations:

1. Rust is probably of SRB BSM residue origin, dust is of naturally-occurring environmental origin.
2. Paint may have originated from processing activities on the flight elements, facility, or ground support equipment.

3. Alpha-quartz is one of the purest forms of the earth mineral silica and tile base component.

4. Organics may be animal or insect remains and deposits.

CONCLUSIONS

The STS-33R mission, as evidenced by the debris analysis report, was successful in minimizing damage from debris. This is also shown to be true by the chemical analysis that was performed on post-flight samples.

The Orbiter window sampling provided results that indicated exposure to SRB BSM residue, paint, thermal protection system materials, cleaning agent residue, and landing site products.

The Orbiter tile samples indicated only tile thermal protection system materials at damage sites.

The Orbiter wing RCC panels provided indication of trace metals, paint, thermal protection system materials, organics, and landing site products.

The ET/Orbiter umbilical area continues to entrap a variety of debris particles. However, none for this mission demonstrate a debris concern.

The Orbiter crew hatch window sample provided only additional indications of residues as noted in other locations.

This mission provided no evidence of orbital debris impacts, unusual debris concerns, or unexplained debris sample analyses.

LANDING SITE SAMPLE ANALYSIS

Sample material was obtained from the lakebed at Ames-Dryden Flight Research Facility, California for debris reference chemical analysis. The sample was submitted to the NASA-KSC Microchemical Analysis Branch (MAB) for material analysis. The specific elemental analysis is shown in the appended Microchemical Analysis Branch report.

The lakebed soil was found to contain albite, alpha-quartz, wairakite, calcite, and muscovite. Optical-microscopy (OM) data suggested the presence of biotite and hornblende. This particular mixture of earthen compounds- Mica (muscovite, biotite); Feldspar (albite); Iceland spar (calcite); Silica (alpha-quartz); and Silicate (wairakite, hornblende) is not peculiar to the climate (desert) or geological area (dry lakebed).

MICROCHEMICAL ANALYSIS BRANCH
DM-MSL-1, ROOM 1274, O&C BUILDING
NASA/KSC
DECEMBER 5, 1989

SUBJECT: Analysis of Post-Launch Debris Samples (STS-33R)

LABORATORY REQUEST NO: MCB-1079-89

1.0 FOREWORD:

1.1 REQUESTER: R. F. Speece/NASA/TV-MSD-22

1.2 REQUESTER'S SAMPLE DESCRIPTION:

Port Launch Debris Samples, LC-39B and MLP

1.3 REQUESTED: Identify material.

2.0 CHEMICAL ANALYSIS AND RESULTS:

2.1 The debris samples were examined and analyzed using infrared spectrometric techniques.

2.2 The two darker and more uneven surfaced pieces were identified as a siliceous-filled polyvinyl acetate-phthalate ester composition, possibly butyl benzyl phthalate.

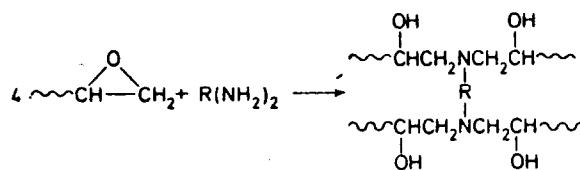
2.3 Several of the grey pieces were examined, analyzed and identified as siliceous-filled epoxy resin materials as noted on the enclosed photocopy.

CHEMIST: W. R. Carman
W. R. Carman

APPROVED: J. F. Jones
J. F. Jones

EPOXY RESINS

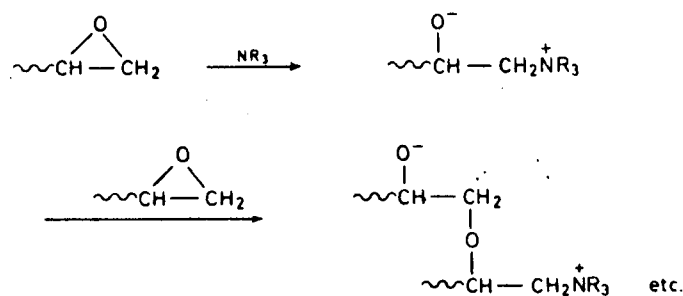
units, while the use of primary di- or poly-amines leads to cross-linkage, e.g.



Examples (some with toxic and/or dermatitic hazards): diethylenetriamine, triethylenetetramine, 4,4'-diaminodiphenylmethane, 4,4'-diaminodiphenyl sulphone, *m*-phenylenediamine, methylenediamine, and amine complexes of boron trifluoride; also acting as amine-type curing agents, especially to provide tough surface coatings, are certain polymeric substances, e.g. polyamides obtained from polymerised fatty acids (Versamids, §23.21.6), while with a high temperature cure both amine- and phenol-formaldehyde resins can be used (OH-groups reacting similarly to NH₂-groups).

(ii) *Secondary amines* Secondary diamines may be used to extend chains without cross-linkage, the reaction being partly as in (i) and partly as in (iii).

(iii) *Tertiary amines* Being devoid of labile hydrogen atoms, these do not operate by direct addition but probably act catalytically (with a trace of water as co-catalyst) opening the epoxy ring at elevated temperatures and initiating polymerisation anionically, e.g.



or by a related mechanism.

Examples: benzyldimethylamine, triethylamine, 2,4,6-tris(dimethylaminomethyl)phenol.

Reactions with amines are accelerated by OH-containing substances, such as phenols and furfuryl alcohol.

(b) *Cure with acid anhydrides*

The complex reactions occurring with these hardening agents may be represented as follows.

MICROCHEMICAL ANALYSIS BRANCH
DM-MSL-1, ROOM 1274, O&C BUILDING
NASA/KSC
DECEMBER 11, 1989

SUBJECT: Debris From Mission STS-33R, OV-103 (Discovery)

LABORATORY REQUEST NO: MCB-1092-89

RELATED DOCUMENTATION: Intercenter Debris Team Requirements

1.0 FOREWORD:

1.1 REQUESTER: S. A. Higginbotham/TV-MSD-22/7-0806

1.2 REQUESTER'S SAMPLE DESCRIPTION:

The particles were removed from orbiter window, OV-103 (Discovery), mission STS-33R landing at DFRF/EAFB, and were identified as follows:

- #1: Alcohol wipe from orbiter window #1.
- #2: Alcohol wipe from orbiter window #2.
- #3: Alcohol wipe from orbiter window #3.
- #4: Alcohol wipe from orbiter window #4.
- #5: Alcohol wipe from orbiter window #5.
- #6: Alcohol wipe from orbiter window #6.
- #7: Alcohol wipe from orbiter window #7.
- #8: Alcohol wipe from orbiter window #8.

1.3 REQUESTED:

1. Identify composition of residual materials collected by wipes and compare to known STS materials.

2.0 CHEMICAL ANALYSIS AND RESULTS:

2.1 Procedure:

The samples were analyzed by means of optical microscopy (OM) and electron microprobe with energy dispersive spectrometry (EDS).

2.2 Results:

- 2.2.1 The particulates were classified into components on the basis of color and texture by OM. The classified components from all samples are listed in Table 1 with the possible identification of each component and elemental analysis.

Table 1

Component ID	Possible Ident.	Elemental Analysis by EDS*	
		Major	Minor
1. Metallics	Cd-Metal Cu-Metal	Cd, Cu	
2. Black Mtls	Rust, Dust	Si, Al, Fe, Ca, Zn, Cu	Ni, K, S, Cl, Mg
3. Red Mtls	Paint	Si, Al, Fe, Ca	Ti, K, Pb, Zn
4. LgtBrn Flakes	K-Si-Al-Fe Flake	K, Si, Al, Fe	Mg, Ti
5. LgtGrey Powder	Si-Al Metals	Si, Al	Fe, S, Ba, Ca
6. Glass Fiber	High Temp. Insulation	Si, Al	
7. Org-Red Mtls	Ce-rich Mtls	Si, Al	Al, Si, S, Fe

2.2.2 Table 2 lists estimated amounts of each component versus sample number.

Table 2

Sample No. Amt. Sample	#1	#2	#3	#4	#5	#6	#7	#8
AMT. OF SAMPLE	S	S	M	M	M	M	T	T
1. Metallics	3(Cu)	X	T(Cd)	X	X	X	X	40(Cu)
2. Rust, Dust & Salt	40	5	5	1	2	3	5	40
3. Paint	X	X	X	X	T	T	T	X
4. K-Si-Al- Fe Flake	2	1	10	2	10	20	10	X
5. Si-Al Mtls	55	56	75	97	98	77	85	X
6. HighTemp Glass Fiber	X	X	10	X	T	X	X	X
7. Orange- Red Ce	X	38	X	X	X	X	X	X
8. Particle Size Range um	1-500	1-110	1-120	1-50	1-150	1-180	1-80	1-100

X: Not detected. T: Trace. S: Small. M: Medium.
(Cd) and (Cu); Cd-, Cu-Metals

3.0 CONCLUSIONS:

3.1 The sample numbers 1, 2, 7, and 8 contained trace to small amounts of particles, and the sample numbers 4, 5, and 6 contained medium amounts of particles.

- 3.2 The sample numbers 1 and 8 contained Cd and Cu metals, respectively.
- 3.3 All samples contained black materials and the black materials were identified to be a combination of rust, dust, and salt components.
- 3.4 The sample numbers 5, 6 and 7 contained trace amounts of paints.
- 3.5 All samples except sample #8 were composed of light-brown colored K-Si-Al-Fe rich flakes (probably micaceous materials).
- 3.6 The sample numbers 1 through 7 contained large amounts of Si-Al amorphous materials. These materials might be formed from the thermal tile upon reentry. Those powdery and grey colored Si-Al rich materials contained small amounts of cerium and lanthanum compound.
- 3.7 The sample numbers 3 and 5 contained Si-Al rich high temperature glass fiber.
- 3.8 The sample number 2 contained orange-red colored Ce rich materials.
- 3.9 The particle sizes were estimated to be in the range of 1 to 500 micrometers.
- 3.10 The Si-Al rich amorphous materials and high temperature glass fiber appeared to be originated from TPS, and the rest of materials appeared to be originated from the surrounding environment.

CHEMIST: H. S. Kim
H. S. Kim

APPROVED: J. F. Jones
J. F. Jones

MICROCHEMICAL ANALYSIS BRANCH
DM-MSL-1, ROOM 1274, O&C BUILDING
NASA/KSC
DECEMBER 18, 1989

SUBJECT: Orbiter Debris, STS-33R

LABORATORY REQUEST NO: MCB-1097-89

RELATED DOCUMENTATION: Intercenter Debris Team Requirements

1.0 FOREWORD:

1.1 REQUESTER: S. A. Higginbotham/TV-MSD-22/7-0806

1.2 REQUESTER'S SAMPLE DESCRIPTION:

A reference sample of EAFB lakebed soil.

- #1: Alcohol wipe from orbiter window #11 (crew module hatch).
- #2: Wipe of streak on LH RCC panel #7.
- #3: Wipe of streak on LH RCC panel #11.
- #4: Wipe of streak on LH RCC panel #15.
- #5: Wipe of streak on R/H RCC panel #14.
- #6: Wipe of streak on R/H RCC panel #18.
- #7: Wipe of streak on R/H RCC panel #19.

- #8: Scrape of streak on RH RCC panel #17.
- #9: White material from SSME #2 nozzle.
- #10: White material from SSME #3 nozzle.
- #11: RH ET/Orbiter umbilical door baggie material.
- #12: Material taken from tile VO70-395009-090.
- #13: Material taken from tile VO70-395008-081.
- #14: Material taken from tile VO70-395037-151.
- #15: Material taken from tile VO70-190002-065.
- #16: Material taken from tile VO70-191008-144.
- #17: Material taken from tile VO70-295009-126.
- #18: Material taken from tile VO70-394046-132.

1.3 REQUESTED:

- 1. Identify composition of EAFB lakebed soil.
- 2. Identify composition of residual material collected and compare to known STS material.

2.0 CHEMICAL ANALYSIS AND RESULTS:

2.1 Procedure:

The samples were analyzed by means of optical microscopy (OM), x-ray diffraction (XRD), and electron microprobe with energy dispersive spectrometry (EDS).

2.2 Results:

2.2.1 Lakebed Soil

The particles are classified into components on the basis of color and texture by OM and the analytical results are listed in Table 1.

Table 1

Component ID	Elemental Analysis by EDS*		Phase ID By XRD & OM
	Major	Minor	
a. White Mtls(30)	Si, K, Al	Fe	Albite, Alpha-Quartz
b. LgtBrnDirt(55)	Si, Al, K, Cl, Fe, Ca	Cl, Mg	Wairakite, Calcite
c. Pink Mtls (1)	Si, Al, K	Fe, Na	
d. Blk Mtls (6)	Fe, Ca, Si, Al	Mg, K, Ti, Cr	
e. LgtGrnMtls(2)	Si, Al, Ca, K	Na, Fe	
f. LgtBrnFlake(6)	Fe, K, Si, Al	Ti, Mg	Muscovite
g. AmberDense Mtls (T)	Fe, Si, Al	Ti, K, Ca, Mg	

2.2.2 Wipes and Materials

2.2.2.1 The particulates are classified into components on the basis of color and texture by OM. The classified components from all samples are listed in Table 2 with the possible identification of each component and elemental analysis.

Table 2

Component ID	Possible Ident.	Elemental Analysis by EDS*	
		Major	Minor
1. Metallics	Ni-Metal	Ni	
2. Black Mtls	Rust, Dust	K, Si, S, Cl, Fe, Ca	Cr, Ti, Ni, Zn
3. Amber Flakes	Muscovite	Fe, K, Si, Al	Mg, Ti
4. Yellow Mtls	YellowPaints	Al, Si, Ca, Fe, Org	Ti, K, Cr
5. White Mtls	Salts, Feldspar	Si, Al, K, Ca, Cl	Fe
6. WhtClr Mtls	Alpha-Quartz	Si	
7. Red Mtls	RTV	Fe, Si	
8. Glass Fiber	Insulation Glass	Ca, Al, Si	
9. Foam	Polyurethane	Foam	
10. Amber Sphere	Microballoon		
11. Black Tile	Black Tile	Si	
12. White Tile	White Tile	Si	

2.2.2.2 Table 3 lists estimated amounts of each component versus sample number.

Table 3

Sample No. Amt. Sample	#1	#2	#3	#4	#5	#6	#7	#8	#9
1. Metallics	X	10	NO	X	X	X	T(Al)	X	NO
2. Rust, Dust	T	50		70	25	45	18	10	
3. Muscovite	X	40		30	X	X	2	X	
4. Paint	5	X		X	5	X	5	X	
5. Salts, Feldspar	X	X		X	10	5	X	X	
6. Alpha- Quartz	35	X		X	X	X	2	90	
7. RTV	X	X		X	X	X	X	X	
8. Insulation Glass	X	X		X	X	T	X	X	
9. Polyurethane Foam	X	X		X	X	X	X	X	
10. Microballoon	X	X		X	X	X	X	X	
11. Black Tile	X	X		X	X	X	X	X	
12. White Tile	X	X		X	X	X	X	X	
13. Organics	60	X		T	60	50	63	X	
14. Particle Size um	1-3000	1-11-		1-180	1-200	1-120	1-230	1-300	

X: Not detected. T: Trace. NO: No Sample
(AL) and (Ni): Al and Ni-metals.

Table 3 (continued)

Sample No. Amt. Sample	#10	#11	#12	#13	#14	#15	#16	#17	#18
1. Metallics	NO	X	X	X	X	X	NO	X	X
2. Rust, Dust		3	X	T	X	X		X	X
3. Muscovite		X	X	X	X	X		X	X
4. Paint		T	X	X	X	X		X	X
5. Salts, Feldspar		X	X	X	X	X		X	X
6. Alpha- Quartz		X	X	X	X	X		X	X
7. RTV		2	X	X	X	6		X	X
8. Insulation Glass		5	X	X	X	X		X	X
9. Polyurethane Foam		80	X	X	X	X		X	X
10. Microballoon		T	X	X	X	X		X	X
11. Black Tile		X	X	10	60	4		95	10
12. White Tile		X	100	90	40	90		5	90
13. Organics		10	X	X	X	X		X	X
14. Particle Size um		1-300	ND	1-80	ND	1-200		1-350	1-300

ND: Not Determined Due To Fibrous Nature. T: Trace.

NO: No Sample. X: Not Detected.

3.0 CONCLUSIONS:

3.1 Lakebed Soil

- 3.1.1 The soil contained white materials, light-brown dirt, pink materials, black materials, light green materials, yellowish brown flakes and amber dense material.
- 3.1.2 The white materials were composed mainly of albite ($\text{NaAlSi}_3\text{O}_8$) and alpha-quartz ($\alpha\text{-SiO}_2$).
- 3.1.3 The light brown dirt was composed mainly of wairakite ($\text{CaAl}_2(\text{SiO}_3)_4 \cdot 2\text{H}_2\text{O}$) and Calcite (CaCO_3) and the light brown flakes were identified to be muscovite ($\text{KAl}_2(\text{Si}_3\text{Al})\text{O}_{10}(\text{OH}, \text{F})_2$).
- 3.1.4 The pink materials, black materials, light green materials and amber materials were not analyzed for phase identification. However, the OM data suggested that the black materials might be composed of biotite ($\text{K}(\text{Mg}, \text{Fe})_3\text{Al}(\text{SiO}_4)_3$) and hornblende [$\text{Ca}(\text{Mg}, \text{Fe})_3\text{Si}_4\text{O}_{12}$].

3.2 Wipes and Materials

- 3.2.1 The sample numbers 1 and 7 contained Ni- and Al-metals.
- 3.2.2 The sample numbers 1, 2, 4, 5, 6, 7, 8, 11, and 13 contained black-colored dust and rust.
- 3.2.3 The sample numbers 2, 4, and 7 contained light-brown muscovite $[KAl_2(Si_3Al)O_{10}(OH,F)_2]$, and the sample numbers 1, 5, 7, and 11 contained small amounts of paints.
- 3.2.4 The sample numbers 5 and 6 contained salt and feldspar ($n NaAlSi_3O_8 - m CaAl_2Si_2O_8$), and the sample numbers 1, 7, and 8 contained Alpha-quartz.
- 3.2.5 The sample numbers 11 and 15 contained trace amounts of RTV, and the sample numbers 6 and 11 contained insulation type glass fibers.
- 3.2.6 The sample number 11 contained large amount of polyurethane foam and small amounts of microballoon.
- 3.2.7 The sample numbers 13 through 18 and the sample numbers 12 through 18 contained black and white tiles, respectively.
- 3.2.8 The sample numbers 1, 4, 5, 6, 7, and 11 contained organics.
- 3.2.9 The particle sizes were estimated to be in the range of 1 to 3000 micrometer.
- 3.2.10 The sample numbers 1 through 11 appeared to contain the contaminants from the surrounding environments and the sample numbers 12 through 18 contained TPS.

CHEMIST: H. S. Kim
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APPROVED: J. F. Jones
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10.0 POST LAUNCH ANOMALIES

Based on the debris inspections and film review, 23 Post Launch Anomalies were observed for STS-33R.

10.1 POST LAUNCH PAD INSPECTION

1. Excessive slack in the GH2 vent arm retract lanyard allowed the cable to wrap around the GUCP swivel housing breaking an electrical connector.
2. A 3'x2' aluminum, facility cable tray cover was found on the deck of the FSS 135 foot level.
3. Three Orbiter Q-felt plugs were recovered south and east of the pad apron near the crawlerway.

10.2 FILM REVIEW

1. A stud hang-up occurred on holddown post #3. A piece of the shim material from the RH SRB aft skirt foot was pulled off by the stud. In addition, stud broaching of the aft skirt foot hole (bore) caused metal debris.
2. A 5-inch debris particle first appeared near HDP #4 and moved diagonally upward near the vehicle. Several other debris particles, which have densities greater than foam, originated from the RH SRB exhaust hole and were ejected upward at high velocities. Some of these particles came close but did not impact the vehicle.
3. Small pieces of surface coating on several base heat shield tiles fell out as a result of SSME ignition acoustics.
4. The third water trough (5th from the RH SRB nozzle) in the secondary sound suppression group had leaked and was nearly empty.

10.3 SRB POST FLIGHT/RETRIEVAL INSPECTION

1. At least 20 MSA debonds were detected on the frustums.
2. Some layers of MSA adhered to blistered Hypalon paint on the frustums and forward skirts.
3. Although the BSM covers were locked in the open position, 7 of the 8 cover attach rings were bent and the covers opened to various positions. Parachute riser entanglement resulted in the cutting of the lines.

4. Cork erosion and some exposed metal occurred on the aft surface of both ET/SRB forward attach point electrical disconnect boxes.

5. The phenolic plates on the RH -Z and LH +Z RSS antennae were delaminated. The -Z antenna was missing some material.

6. Factory joint EPDM moisture seals were debonded:

RH	FWD segment	160 deg	leading edge	15"x1" deep
RH	FWD segment	270 deg	leading edge	1/2" deep
RH	FWD segment	210 deg	trailing edge	1.5" long
LH	AFT segment	0-360	trailing edge	2.5" deep in some places

7. The phenolic material on both SRB kick rings delaminated in several locations.

8. K5NA bolt head thermal protective domes on both kick ring phenolic trailing edges were missing with sooted substrate.

9. K5NA was missing from all 8 aft BSM nozzles.

10. Holddown post #3 aft skirt foot hole (bore) showed evidence of stud hang-up. Thread marks from the stud were impressed around the forward inner aluminum surface of the hole. The stud abraded a 1/2-inch deep chamfer inclined 45 degrees on the inboard aft edge of the hole. The aft facing surface of the foot was charred by ascent heating where 40% of the shim material had been pulled off the foot at liftoff by the stud.

11. Instafoam was missing from the aft side of the ETA ring behind the IEA. Broken foam and exposed cork substrate were sooted. The area of missing foam measured 3 feet long by the width of the ETA ring.

10.4 ORBITER POST LANDING INSPECTION

1. Two trailing edge tiles on the RH side of the rudder/speed brake were damaged. The damage was not caused by debris impacts but probably were the result of the combined launch environment (acoustics, heating, etc).

2. The SSME engine mounted heat shield closeout blankets were damaged: 3 to 6 o'clock on SSME #1, 12 to 3 o'clock on SSME #2, and 9 to 10 o'clock on SSME #3.

3. One Q-felt plug was missing from a closeout panel screw hole on the base heat shield.

4. Several pieces of gap filler sleeving material were loose on the RH OMS pod.

5. The EO-1 ordnance device had rotated forward and broken the LH bulkhead pyrotechnic connector backshell. There is also evidence of contact on the ordnance device LH spring housing.

Report Documentation Page

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16. Abstract A Debris/Ice/TPS assessment and photographic analysis was conducted for Space Shuttle Mission STS-33R. Debris inspections of the flight elements and launch pad are performed before and after launch. Ice/frost conditions on the External Tank are assessed by the use of computer programs, nomographs, and infrared scanner data during cryogenic loading of the vehicle followed by on-pad visual inspection. High speed photography is analyzed after launch to identify ice/debris sources and evaluate potential vehicle damage and/or in-flight anomalies. This report documents the debris/ice/TPS conditions and photographic analysis of Mission STS-33R, and their overall effect on the Space Shuttle Program.					
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